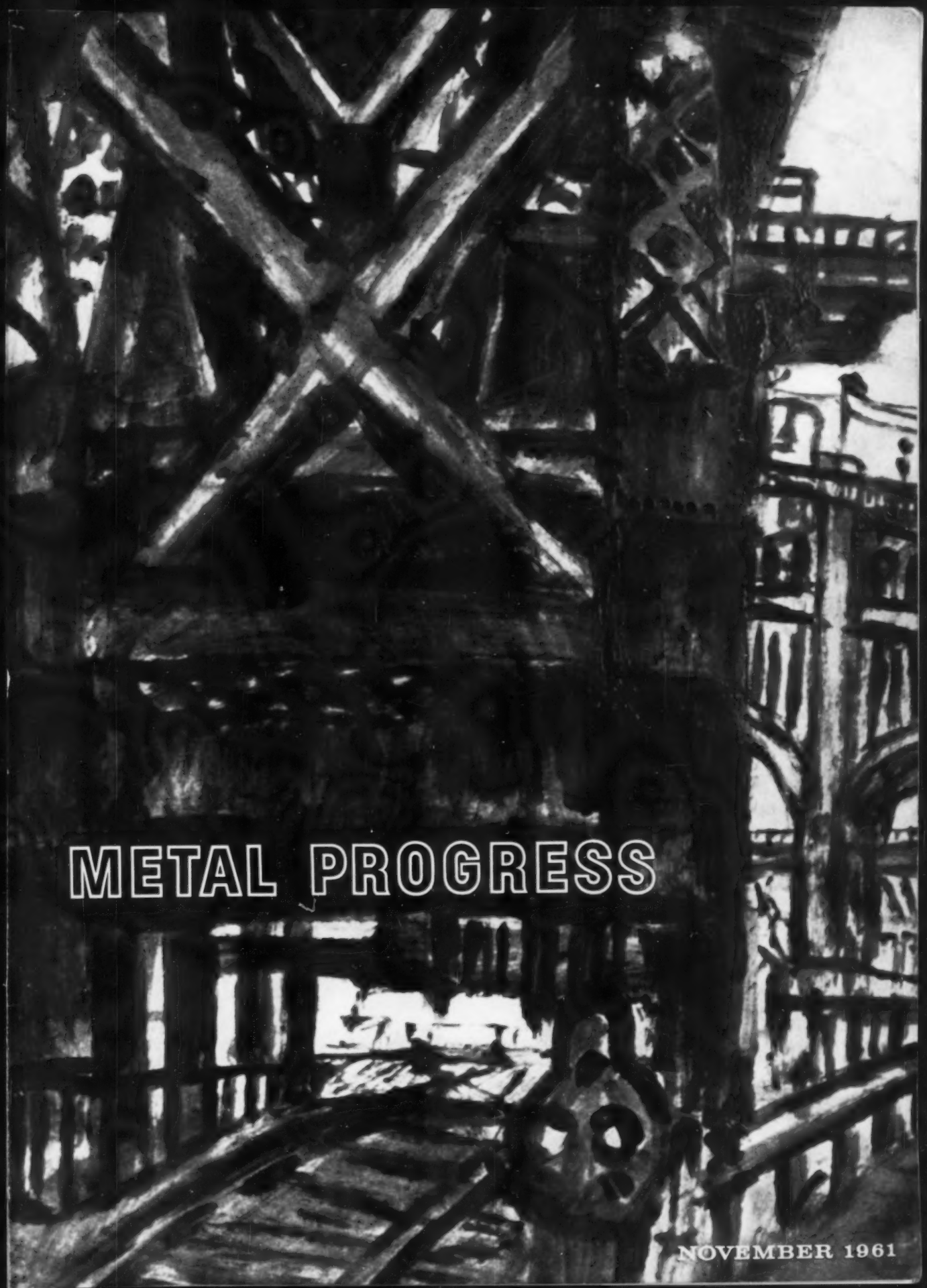


METAL PROGRESS

NOVEMBER 1961

OPEN UP: for better drawing quality steel

The uniformity of anneal possible only through the Open Coil Process means a more uniform Rockwell with more uniform drawing quality throughout the entire coil. This enables a steel producer to duplicate orders, providing the same steel time after time, so that one stamping plant will be using precisely the same steel as another — an important consideration for decentralized manufacturing. "Stickers" are eliminated, and it is now possible to roll smoother deep-draw steels with better surface qualities for improved end products. For further information write the *Lee Wilson Engineering Co., Inc., 20005 Lake Road, Cleveland 16, Ohio.*

Circle 1923 on Page 48-B

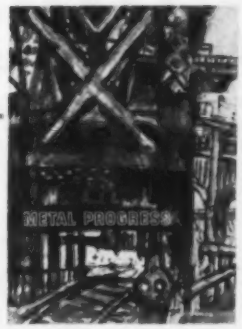
Lee Wilson

Originators and Leading Producers of Open Coil and Single Stack Furnaces

METAL PROGRESS

THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING

November 1961 . . . Volume 80, No. 5



COVER: As a change of pace from our usual four-color process front covers, MP's art director chose an interesting two-color combination – yellow and black – for this reproduction of HOWARD STOLLER's entry in the 1961 *Metal Progress* Cover Contest at the Cleveland Institute of Art.

Technical News in Brief

Miniature Zinc Die Castings Offer Cost Advantage . . . Tellurium Improves Machinability of Steel . . . Consumable Electrode Vacuum Furnace With Lazy-Susan Device . . . Research on Copper Promises Improved Materials . . . More Zinc for Automobiles . . . Induction Furnace Produces Cast Iron for Valve Bodies . . . Difficult Tungsten Shapes Forged Successfully . . . Beryllium Corp. Dedicated New Plant . . . How to Make Reliable Seam and Spot Welds in René 41 Alloy 7

Modern Heat Treatment

A Superior Microstructure for Optimum Induction Hardening, by Richard J. Gould 66

In the development of the hardened and tempered microstructure of steel, as commonly used in induction hardening, there exists a critical carbide particle size. A slight deviation from this critical size will result in either optimum or inferior case hardnesses. Also, prolonged tempering times adversely affect the response of the microstructure to induction hardening.

Temperature Control in Titanium Processing, by P. C. Barr 71

For processing, titanium should be heated only to the lowest possible forming temperature. Though protective atmospheres are not needed, room air should be kept from inside the furnace as much as possible.

Heat Treating in a Vacuum, Staff Report 75

Vacuum heat treating has much potential for producing parts which meet critical hardness, tolerance and surface finish requirements.

Engineering Articles

A Method for Strengthening Semiaustenitic Stainless Steels, by D. C. Ludwigson 78

Both the formability and strength of a semiaustenitic stainless steel can be improved to a degree by mild deformation followed by a stabilizing heat treatment.

Aluminum 2219 . . . New Alloy for High-Strength Welded Structures, by F. R. Collins, F. G. Nelson and I. B. Robinson 82

A heat treatable alloy which retains its high strength at temperatures of 450 to 700° F., 2219 also has demonstrated superior weldability. Weldments perform well at subzero and at elevated temperatures.

Welding 2219 Aluminum for Bomarc Fuel Tanks, by Stanley L. Sears and Richard S. Crial 88

This important application, the first for 2219, has verified the manufacturing adaptability of the alloy. No other aluminum alloy has comparable reliability in pressure-vessel applications where postweld heat treatment is required.

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SUPERTHERM*

Centrifugally cast for 2300°F

End Product is longer life and lower maintenance for heat-resistant parts . . . radiant tubes, furnace rolls, blowpipes, gas generators and other tubular or tubular-section components.

Supertherm* is a 26% Cr—35% Ni alloy strengthened and stabilized with cobalt and tungsten. Supertherm* has proved its capability within the 1800-2300° F range and under very severe heat-cycling conditions. In many cases, the alloy has extended service life two to three times over previous operations.

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For further information on Supertherm* and its applications, contact your nearest Electro-Alloys representative. Or write to Electro-Alloys, and a technical bulletin will be forwarded to you.

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METAL PROGRESS

Malleable Irons . . . Versatile Engineering Materials, by Hans J. Heine 94

The foundry industry has made significant progress in advancing the technology of malleable irons. More is known about machinability and recent studies confirm their excellent stress-rupture properties to at least 800° F.

A Metal for Service at Both Cryogenic and Ultrahigh Temperatures, by H. R. Ogden and I. Perlmutter 97

Tantalum alloys may be useful for parts requiring a combination of toughness at cryogenic temperatures with strength at high temperature.

Stainless Steels for High-Strength Welded Structures and Components, Staff Report 100

Stainless steels, including the more recent precipitation-hardening grades, have become important engineering materials for welded structures.

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How to Get the Most From Phosphating Systems – III, by George H. Pimbley 108

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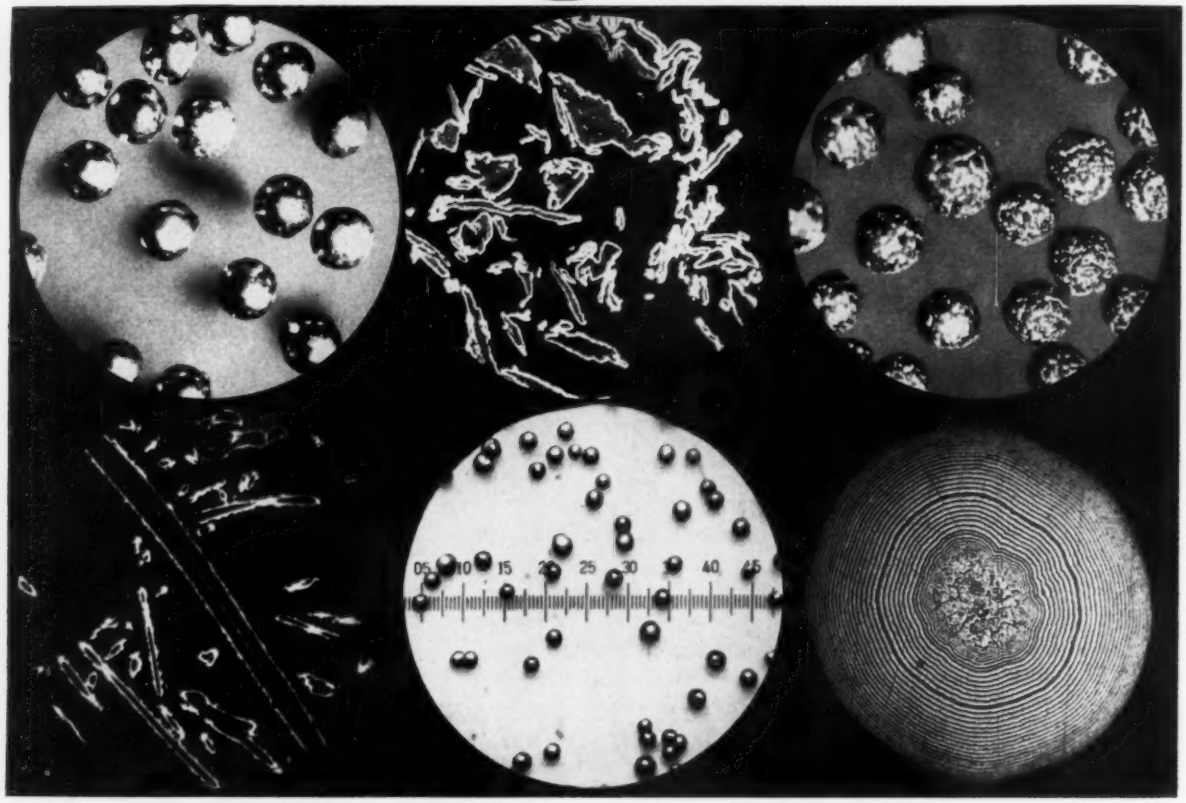
For metallurgists with imagination . . .



An important advance in metal powders!

Clad powders with metal and non-metal cores open the way to new materials and technologies!

Out of the laboratory and into commercial use comes a concept that promises to advance metal powder technology.

Composite powders—made by Sherritt's patented process—consist of finely divided metal or non-metal particles coated with nickel or cobalt. The composition of these particles can be controlled to produce a wide range of materials with improved or unusual properties.

Composites with metallic cores include nickel-aluminum and nickel-tungsten. Various grades of graphite have been coated with nickel. High phosphorus alloys—not easily formed by conventional methods—are readily prepared with nickel or cobalt as the cladding. Carbides of tungsten, titanium, tantalum, chromium and silicon, and oxides such as alumina, silica, zirconia are used as core materials. Even ceramics and fibrous materials, such as asbestos and alumina-silica wool, have given good results. And, most recent of all, are coated-plastic powders, such as Teflon* coated with nickel.

Applications range from electrical resistance alloys, controlled expansion alloys and hard facing alloys to welding rods, permanent magnets, cemented carbides, bonded abrasive tools, and many others.

How will these metal-coated powders improve *your* processing or your products? What new uses will you make of them? If clad powders spark your imagination—or your curiosity—write our Technical Literature Department for free Booklet, "Metal and Composite Powders." Or, ask a Sherritt Contact Metallurgist to call. Address request to Marketing Division, Sherritt Gordon Mines Ltd., 25 King St. West, Toronto, Canada.

*Du Pont Trademark

SHERRITT GORDON MINES LIMITED

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PRESS BREAKS

THE EDITOR HAS JUST RETURNED from a trip deep in the heart of Texas where he participated in a meeting of the Atomic Energy Commission's Welding Forum in San Antonio. This group, under the leadership of genial Frank Davis, formerly with the A.E.C. and now associated with the Southwest Research Institute in San Antonio, has been meeting annually for some ten years to present papers and discuss developments in welding, brazing and fabrication technology, as related to problems in the nuclear field. The meeting is held on a classified basis so that the participants may discuss their problems freely. Even so, the sessions provide a wealth of new ideas for articles in *Metal Progress* which can be presented on a basis to serve the broad technological interests of industries which can profit from techniques devised by atomic scientists and engineers. So in future issues of our favorite magazine you will be reading about such things as ultrasonic welding, optimum design for brazed joints, joining dissimilar metals, welding beryllium – articles developed from ideas presented at the A.E.C. Welding Forum.

The Editor was called upon for a few words just before adjournment and among other things he emphasized that one of the most urgent problems in metal science and technology is the need to disseminate new information as quickly and as widely as possible. A specialized meeting, such as the Forum, is a rapid way of communicating to those working in related technologies. However, it is our responsibility as editors to glean information from the technical sessions and make it available to engineers working in the various fields of the new technologies as well as to interpret the intelligence in a way that those engaged in everyday manufacturing areas can benefit.

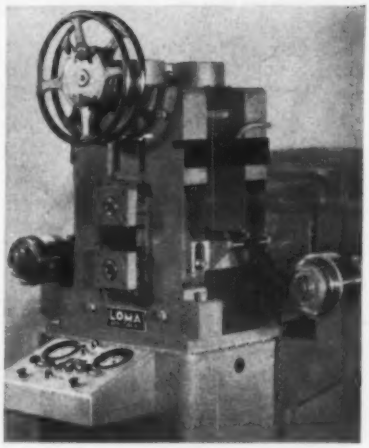
The Forum opened this year on a sad note. The late Editor-in-Chief of *Metal Progress*, Ernest Thum, was not in his usual place. Ernest Thum attended these meetings with a great deal of interest and supported Frank Davis's Forum to the fullest extent. Fittingly, the Forum offered its tribute:

> During the year the Atomic Energy Commission Welding Forum and many of us personally lost a faithful friend. Ernest E. Thum, Editor-in-Chief of *Metal Progress*, was truly interested in the program of the Forum, and with his philosophy and technical knowledge, added much to the worthwhile nature of the Forum's activities. Therefore, be it resolved and published in the proceedings of this meeting that those present confirm once again their appreciation for the efforts put forth by Ernest Thum in our behalf. His life was truly worthwhile, and he contributed much to the search for technical truth to which he dedicated his life.

THE EDITORS

NEWS FROM

LOMA



This rugged and versatile reversing 2-high / 4-high combination mill brings high-precision rolling of thin-gauge ferrous and non-ferrous strip within reach of the smaller re-rolling mill, metals pilot plant and research laboratory. Occupying only 35 sq. ft. of floor space and involving a cost of less than $20,000, the machine handles up to 6 in. wide strip at rolling speeds up to 250 ft. per min. with accurate front and back tension control.

The new 8 in. mill is furnished with two sizes of 4-high work rolls, made of either alloy tool steel or solid tungsten carbide: the 1½ in. size is used for normal cold reduction down to 0.002 in. thickness, and the ¾ in. size allows special ultra-thin finishing to gauges of less than 0.001 in. In the 4-high setup, the machine handles up to ¼ in. gauge; the 2-high arrangement is used for the hot or cold breakdown of heavier materials up to 1 in. thick, but is also available for skin pass rolling of thin strip.

The production of close-tolerance stock is assured by an exceptionally rugged mill design, employing steel housings of 160 sq. in. post area, super-precision needle roller journal bearings of 175,000 lb. separating force capacity, a heavy-duty mill drive with herringbone gearing and universal joint spindles, and twin-handwheel worm drive screwdowns. The machine is powered by a four-speed reversing drive offering constant horsepower from 40 to 250 ft. per min. rolling speed.

The outstanding feature of the new machine is its reversing strip coiling attachment allowing the two-way rolling of strip under tension control with no more effort than a mere flick of a selector switch. Mounted on brackets at either side of the mill, the two coiling shafts carry 8 in. diameter reels designed for a coil buildup of 6 in. Both shafts are driven from the pinion stand and are provided with dual air-operated slip clutches and brakes of ultra-sensitive, low-inertia design. Selective operation through solenoid valves and pressure regulators precisely controls the front and back tensions desired for any given mill pass.

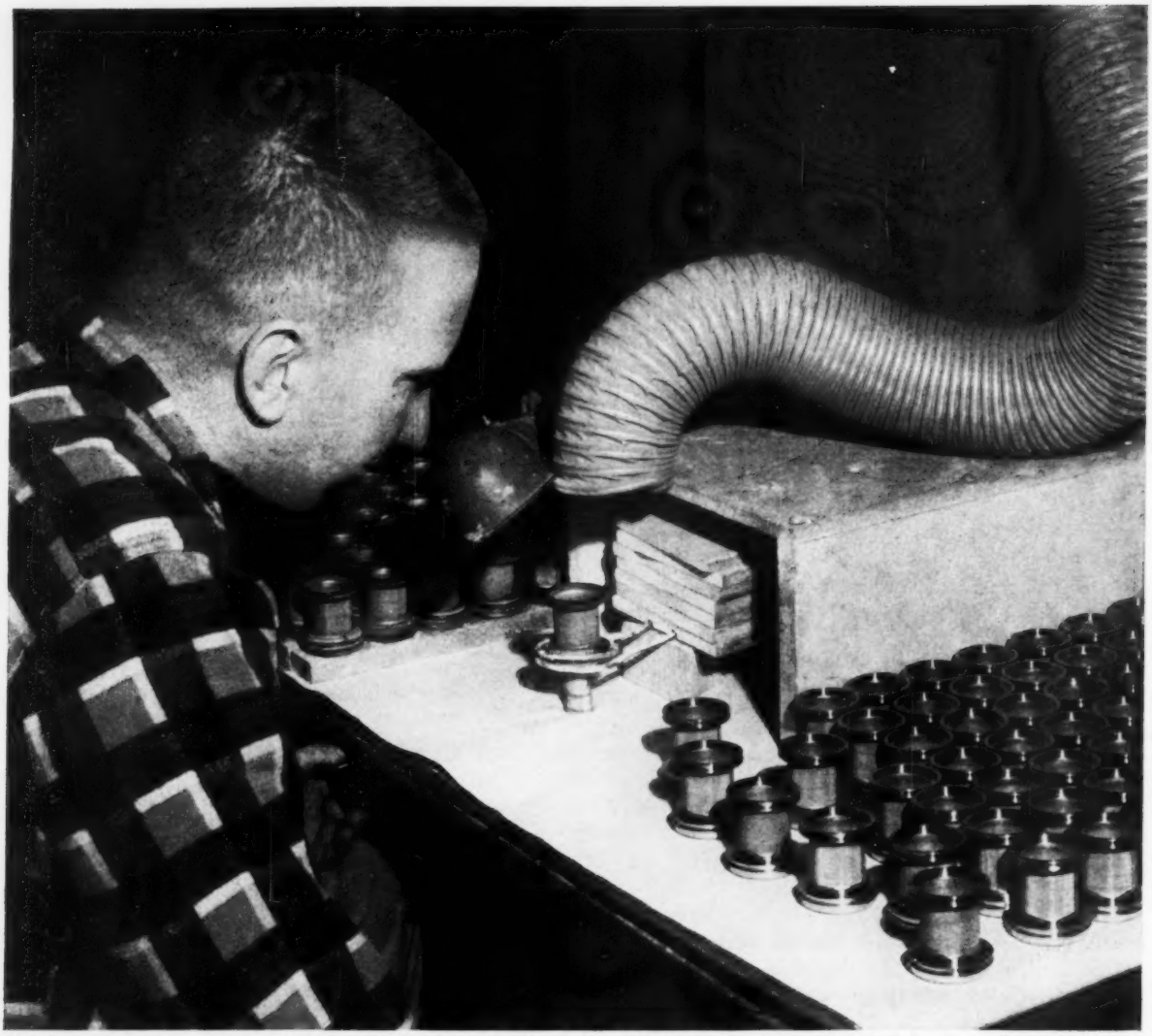
LOMA

MACHINE MFG. CO., INC.

114 East 32nd Street

New York 16, N. Y.

Circle 1875 on Page 48-B



Stainless steel filters are induction brazed at Dynamic Filters, Inc., Detroit, Mich., using EASY-FLO brazing alloy and Handy Flux for 100% joint integrity.

SILVER BRAZING—the precise tool for precision fabricating

The ability of silver brazing to serve fabricators literally through thick and thin is well illustrated by the experience of Dynamic Filters, Inc.

This firm manufactures fine filters for industrial, aircraft, missile, nuclear and marine use by bonding woven wire cloth of desired mesh to a coarser backing screen, forming and joining to required shape and attaching necessary fittings.

Since the filters must be capable of screening out particles ranging down to 2 microns in size, often under heavy pressure, any flaws in joint material or method would naturally be fatal. Dynamic Filters gets complete joint reliability by silver brazing with Handy & Harman EASY-FLO brazing alloys and Handy Flux. How do they know? They inspect all joints 100%.

Equally decisive in their choice of silver brazing is its compatibility with both the relatively thick fittings and thin wire mesh. EASY-FLO melts quickly at relatively low temperatures so metal is not annealed, oxidized or otherwise damaged, forms a thin, molten metal film that penetrates into small voids and capillary spaces, then solidifies to form strong, neat joints requiring little or no finishing.

Add to this the advantages of volume production at often negligible expenditure in brazing materials and you'll see why silver brazing is becoming more and more the favored method for beating fabrication costs. Get complete information—send for a copy of our data-packed Bulletin 20. It's yours for the asking. Write today.

HANDY & HARMAN
850 Third Avenue, New York 22, N.Y.

Circle 1876 on Page 48-B

Miniature Zinc Die Castings Offer Cost Advantage

A miniature counter assembly weighing less than ½ oz. and with a cross section smaller than the area of a dime, die cast from a zinc alloy by Hadlock & Temte, Inc., Chicago, won the grand prize in an annual competition sponsored by New Jersey Zinc Co. The assembly (see photo) consists of a two-piece housing, four counter wheels and five tiny gears, the smallest being a ten-tooth bevel gear only 0.063 in. high. Dimensions on individual parts of this assembly were held to tolerances of 0.001 to 0.002 in., except those of housing hole diameters which were within 0.0005 in.

A cost saving of 91.5% per unit was achieved by die casting over machining the parts from bar stock. The assembly is a decimal-type counter for an elapsed time indicator such as are employed in digital computers.

Another entry in the contest was a zinc die cast louver used in ventilating an aircraft navigation equipment case. Since it exhausts air in a horizontal plane and away from the pull of the fan intake, the vanes must be closely spaced. Contoured ribs forming 100 openings are only 0.025 in. thick. Die casting permitted the addition of flat vertical vanes which act as a radiofrequency shield, eliminating costly perforation of the case. A bevel frame enables snap action installation into a flanged hole in the case, eliminating spot welding or the need for any other fastening. Fit is extremely tight and vibration-free. The louver was die cast at half the installed cost of the previous stamping.

Still another entry was a time recording lock assembly made from 15 zinc die castings for 28 different door installations. The mounting plate on this lock assembly replaces six different plates previously used. The single plate has all the various mounting holes for different installations flashed over. All holes are coded with cast lettering so that only the holes needed for a specific installation are punched out. The 15 different castings are made from three individual dies and three unit dies, resulting in production economies. Very few secondary operations are required.

COUNTER ASSEMBLY FOR DIGITAL COMPUTER
Die Cast of Zinc to Close Tolerances With Saving of 91.5%

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Technical

NEWS

In Brief

Tellurium Improves Machinability of Steel

Machining speeds of over 600 surface ft. per min. were attained in a six-spindle screw-machining operation on spark plug shells made from tellurium-bearing steel. For this operation, La Salle Steel Co. supplied 13/16-in. hexagonal bar stock in the cold finished condition. Nominal composition of this grade, which was developed by Inland Steel Co., is 0.13 C max.; 0.80 to 1.20 Mn; 0.04 to 0.09 P; 0.40 to 0.50 S; 0.15 to 0.35 Pb; plus tellurium. Only a few hundredths of 1% by weight of tellurium is needed to enhance machinability of the steel.

One user found that a machine part knurled, shaved, grooved and tapped and drilled with two cross holes could be produced in 6½ sec. using the tellurium-bearing steel in contrast with 12 sec. for a comparable grade of leaded steel. After preliminary tests, machine speed was increased to 618 surface ft. per min.; feed was 0.0035 in. per revolution. This is 3½ times the machining speed of the standard screw-machine steel, B1112. High speed steel was used in the cutting tools.

Consumable Electrode Vacuum Furnace With Lazy-Susan Device

A consumable electrode vacuum arc furnace with "lazy-susan" type of crucible arrangement will be installed at Special Metals, Inc., New Hartford, N. Y., early in 1962. This installation, which has an estimated annual capacity of 4 to 8 million pounds, is now being constructed in Germany. The first of its kind in America, it has an over-all height of 57 ft. and will occupy about 1000 sq.ft.

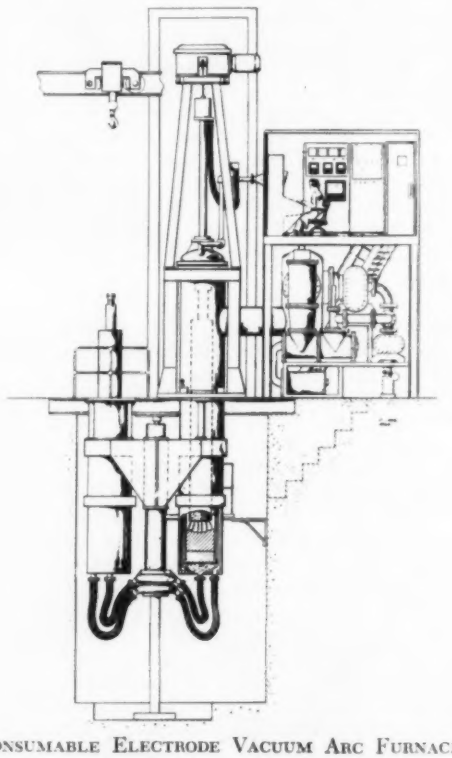
As the diagram shows, water-cooled copper crucibles are below the surface of the floor on a "lazy-susan" device. While one crucible is in position in the melting chamber, the other one is unloaded and a new electrode (ingot) installed ready for remelting. With this device, downtime between melts is reduced considerably because the crucibles are merely rotated into place.

The company's primary objective is to remelt ingots produced in the vacuum induction furnace. Vacuum arc remelting and pouring will be closely controlled to produce ingots with sound structures and complete homogeneity. This is important in ingots and billets for turbine wheel forgings.

Research on Copper Promises Improved Materials

Some clues as to future materials which may be available as copper-base alloys or which will result from use of copper as an alloying element came to light last month when Dr. Charles H. Moore, technical director, Copper Products Development Assoc., discussed the Association's research program. The occasion was the opening of an office in Detroit by the Copper and Brass Research Assoc. to expand engineering and metallurgical services on copper metals to the automobile industry. Chief of the office is Richard D. Chapman, formerly assistant chief engineer, basic science research of Chrysler Corp., and member of A.S.M.'s Technical Council.

Dr. Moore reported that 34 producers representing the copper industries of Canada, Great Britain,



CONSUMABLE ELECTRODE VACUUM ARC FURNACE
Lazy-Susan Arrangement Will Handle Ingots Weighing up to 10 Tons

Technical

NEWS

In Brief

France, Italy, West Germany, Norway, Sweden, Denmark, South Africa, Australia, as well as the United States, are supporting the research effort. One group of studies seeks to develop tarnish-free surface for copper products, ultrahigh-strength structures and electrically insulating copper composites. Three types of surface treatment are being investigated to solve the tarnish problem. Two other studies, while not motivated by the search for a so-called "stainless" copper, could throw much light upon it. One has to do with the mechanics of surface reactions of copper and the other deals with the effect of surface dislocations on physical properties.

Dr. Moore pointed out that studies on the use of copper as an alloying element in cast iron will be of significance to the automobile industry, which is now working to develop high-strength, thin-wall cast iron for engine blocks.

The information that has evolved thus far confirms what has been known for some time – that small additions of copper improve a number of the physical properties of gray cast iron. One of the most important is a decrease in the tendency to chill. This results in cast iron which conceivably could be used to produce thin-wall sections for lightweight engine blocks. These alloys would also have better machinability.

Another important benefit, according to Dr. Moore, that can be expected from copper – perhaps even more important than the chill effect – is the corrosion resistance it is known to impart to iron and steel alloys when added as an alloying agent. Internal combustion engines that use sulfur-containing fuels have been known to experience severe corrosion wear in the cylinder walls.

Recent investigations in England have indicated that the silicon content of gray cast iron is an extremely important factor in the corrosion of cylinder blocks where high-sulfur fuels are used. Analysis by the electron microprobe of a typical gray iron structure containing about 3% Cu and 2% Si indicates that the copper has distributed itself uniformly throughout the matrix of the iron. This composition also exhibited improved corrosion resistance over unalloyed gray iron.

More Zinc for Automobiles

Automobiles will employ greater amounts of zinc alloys in 1962. Full size cars will have 80 lb. of zinc die castings (the 1961 cars had 75 lb.). The new compact cars will have 35 lb. of die castings in contrast with 30 lb. in the 1961 models.

Zinc will also be used in the form of galvanized sheet for rocker panels, quarter sections, and mufflers. One car producer will apply galvanized steel sheet in areas of high corrosion susceptibility. In 1954 the average car contained only 8.9 lb. of galvanized sheet. By 1958 this had increased to 63 lb. per car. In 1961 the compact car employing the unitized body used about 100 lb. of zinc-coated steel.

Cast Iron Valve Body
Cupola Metal Was Duplexed in an Induction Furnace Before Being Poured

Induction Furnace Produces Cast Iron for Valve Bodies

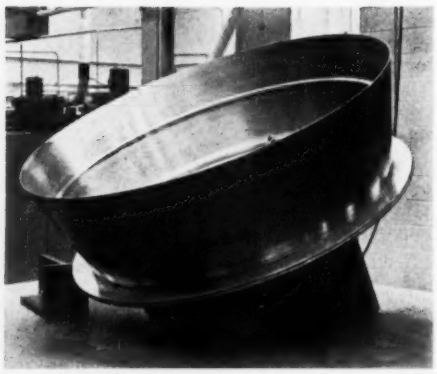
Shown in the accompanying photograph is a hydraulic valve body (before and after machining) cast by the Sibley Machine and Foundry Corp., South Bend, Ind. Before being cast, the iron received a special treatment – it was further processed in a new induction furnace (designed by Forni Elettrici A. Tagliaferri of Milan, Italy, and installed by Hevi-Duty Electric Co., Watertown, Wis.) after the cupola melting operation. This treatment was needed because cupola iron ordinarily has about 3.50% C and 2.50% Si. About 5% low-carbon steel is added to the iron in the induction furnace. This addition dilutes the iron to reduce the carbon and silicon contents. Further details on this operation will be presented in an article "An Italian Induction Furnace for Cast Iron", which will appear in the 10th Annual International Issue of *Metal Progress* (January 1962).

Difficult Tungsten Shapes Forged Successfully

Thin-section structural shapes in tungsten alloys (which melt above 6000° F.) are being forged by

Technical NEWS

In Brief



MACHINED PART FOR AEROSPACE VEHICLE
Large Beryllium Component, Machined to 0.040-In. Thickness, Weighs 12.5 Lb.

Tapco, Div. of Thompson Ramo Wooldridge, Inc., Cleveland. Web and rib thickness of 0.130±0.015 in. are achieved with a surface finish of 30 micro-in. (rms.) and draft angles as low as 1°.

The bar stock, prior to forging, was produced by extruding tungsten alloy ingots at up to 4000° F. in a 700-ton press designed to handle difficult metals at high speeds and pressures. The ingots were heated for forging in vacuum furnaces. High-purity argon atmosphere was used during heating of ingots. Special extrusion die coatings were developed to prevent the 4000° F. ingot from melting the forging dies. The bar stock was forged in three steps. Careful control of metal flow patterns, temperatures, and lubricants enabled commercial die steels to withstand the repeated forging blows.

Beryllium Corp. Dedicated New Plant

The accompanying photo shows the largest piece of beryllium machined in such a thin section. No other metal could be machined to comparable thickness because it would flex in the process. This part, incidentally, was unveiled last month at the dedication of a new plant for fabricating beryllium by the Brush Beryllium Corp., Cleveland.

This component is a prototype of a part for aerospace vehicles. It ranges from 53½ to 63 in. in diameter; height is 18⅝ in.; wall thickness is only 0.040 in. and the weight is a mere 12.5 lb.

From Here and There

Armco Steel Corp. announces a new work-hardening stainless steel alloy (18-9 LW) for severe cold heading, swaging and other cold forming applications. Nominal composition of this alloy is 0.10 C max.; 2.00 Mn max.; 0.045 P max.; 0.030 S max.; 1.00 Si max.; 17.0 to 19.00 Cr; 8.00 to 10.00 Ni; and 3.00 to 4.00 Cu. This steel is expected to be used for fasteners and related parts in automotive, aircraft, missile, chemical equipment and appliances where corrosion resistance is important.

• • •

Recently the Pratt & Whitney Aircraft Div. of United Aircraft Corp. tested successfully a new high-strength steel rocket motor case. The case developed a hoop stress of 285,000 psi. with maximum measured stress of 311,000 psi. at rupture. The test program shows that high-strength rocket motor cases can be fabricated from steel heat treated to 240,000 psi. min. yield strength.

• • •

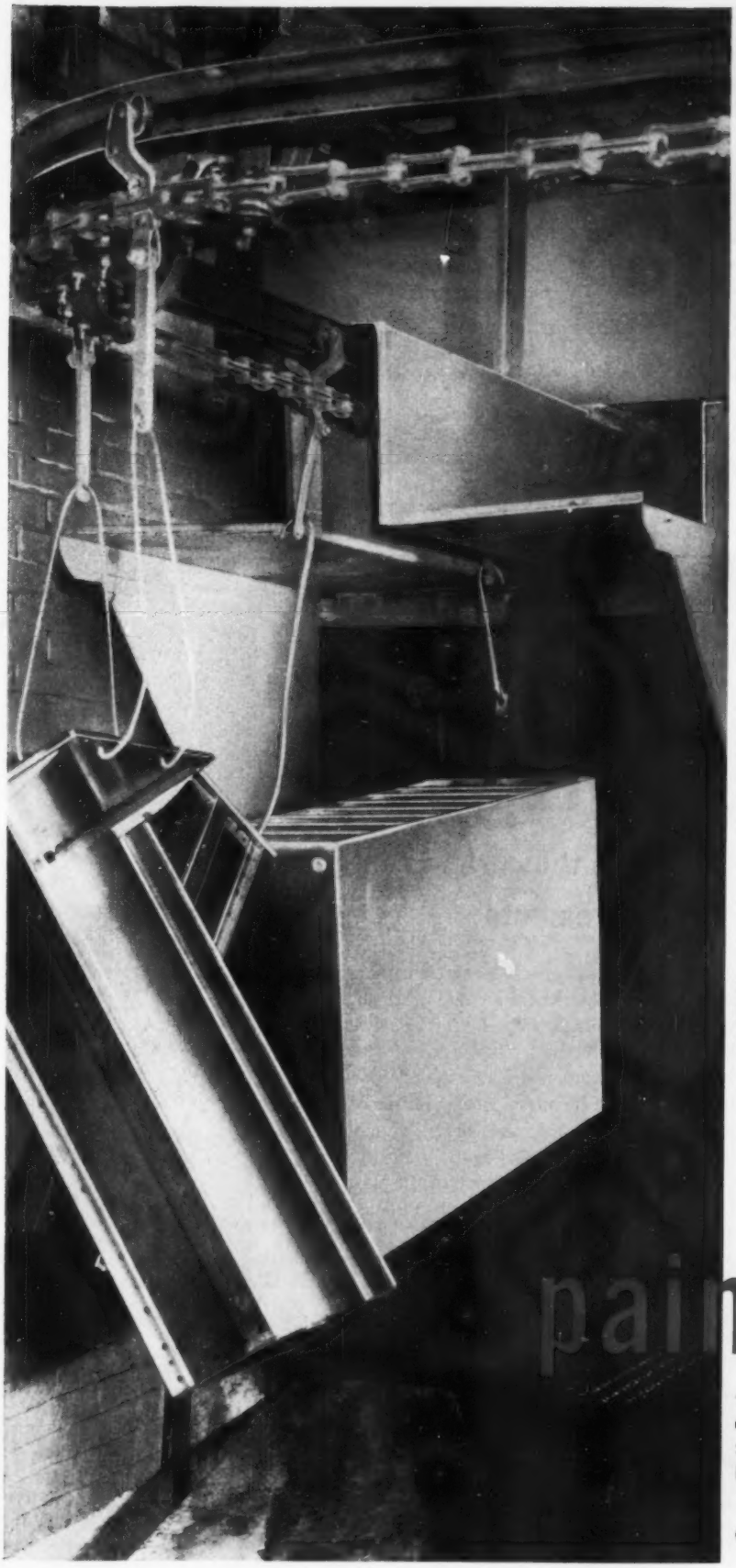
Commercially pure cobalt with good ductility and workability is now supplied in coiled strip. Sizes available: 0.005 to 0.025-in. thicknesses and ¼ to 6-in. widths. This strip, which is produced by Gordon Mines Ltd., Toronto, will be applicable where corrosion resistance, strength at high temperatures, and magnetic properties are required.

• • •

Pullman-Standard is producing 40 railroad hopper cars from aluminum plate, extrusions, and castings for the Louisville & Nashville Railroad. High-strength weldable aluminum alloy 5454 was chosen for plate and extruded parts. Each car will weigh 53,000 lb., or 12,000 lb. less than a comparable all-steel car.

How to Make Reliable Seam and Spot Welds in Rene' 41 Alloy

In the December *Metal Progress*, B. M. Wahlin and D. R. Coles of the Boeing Co. describe their process of making high-quality seam and spot welds in René 41. Precautions based on the metallurgical behavior of the alloy must be observed. Mill-annealed sheet with fine grain structure and randomly dispersed carbides is preferred. The authors stress that postweld cooling rate and initiation and magnitude of the forging force must be precisely controlled to avoid cracking.



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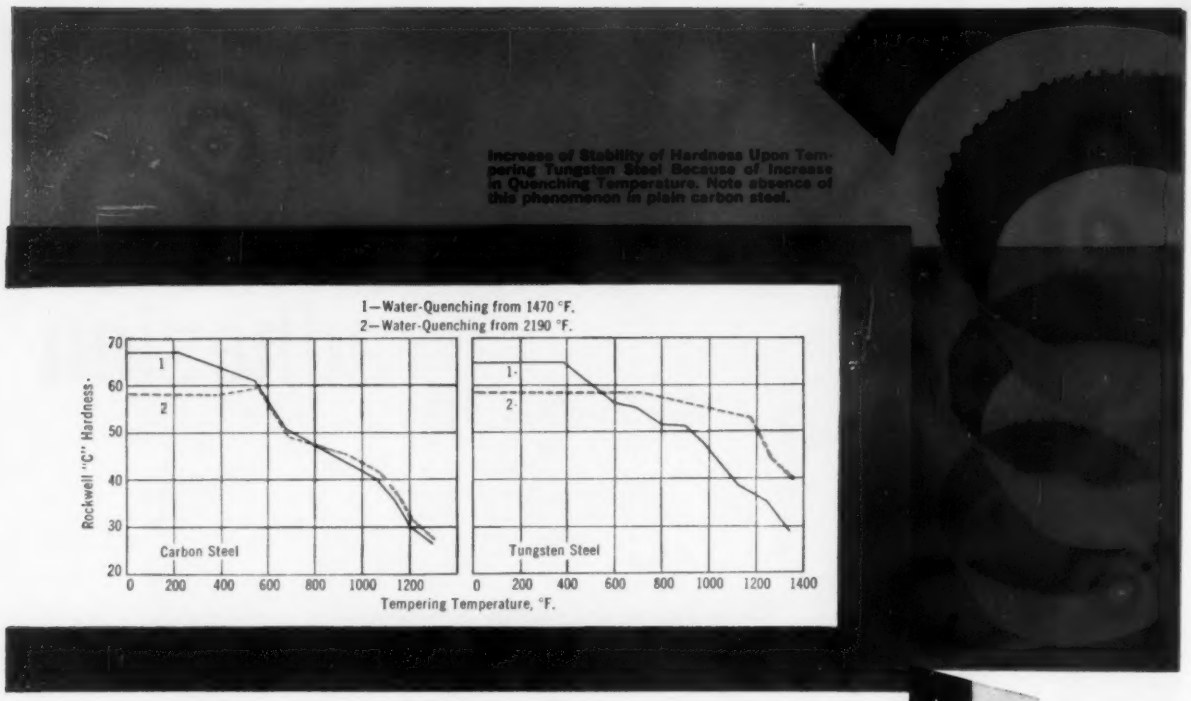

Increase of Stability of Hardness Upon Tempering Tungsten Steel Because of Increase in Quenching Temperature. Note absence of this phenomenon in plain carbon steel.

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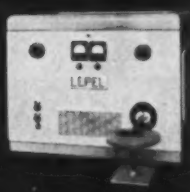

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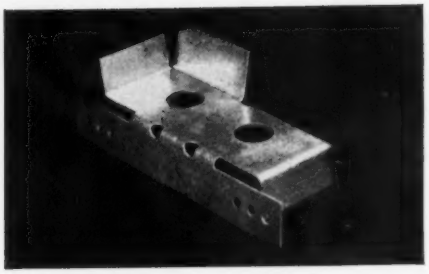
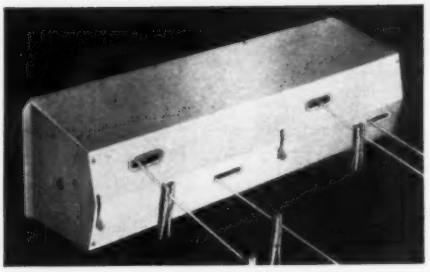


Armco ZINCGRIP Steel



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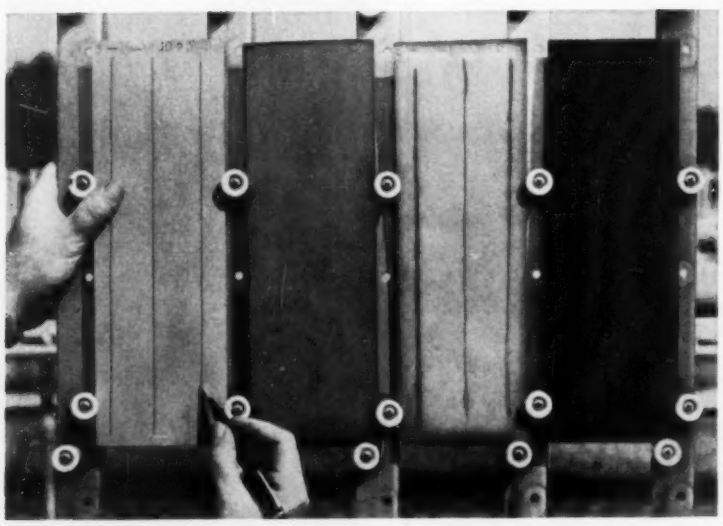

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After 3-years' exposure outdoors, paint holds tightly to ZINCGRIP A, PAINTGRIP (far left). No rust even where scratched. No rust on the unpainted sample, either (second from left). Samples on the right are phosphate-treated cold-rolled steel, one painted, the other unpainted. Paint has suffered. Rust is evident on the unpainted sample.

1. NEW ARMCO ZINCGRIP® A, PAINTGRIP®. This *new* kind of hot-dip zinc-coated steel is specially prepared to take a paint finish that's every bit as attractive as a paint finish on cold-rolled steel! It's *spangle-free,* holds paint *tighter and longer,* permits *twice as many spot welds* as ordinary galvanized before electrode tips need redressing. It's available *now* in commercial quantities.

2. ARMCO ZINCGRIP STEEL has a tightly adherent zinc coating that gives products durable protection at an *average cost of about 2⅓ cents per square foot.* Savings: About .92 cents per square foot over typical cost of painting. The door part pictured, for example, was previously fabricated from cold-rolled steel, then painted for protection. It is now made of Armco ZINCGRIP at a significant saving.

3. ARMCO ALUMINIZED STEEL Type 1 means greatly increased service life—for mufflers and other consumer, commercial and industrial products menaced by heat and corrosion. Furnace, heater and appliance parts made from this special hot-dip aluminum-coated steel won't discolor to 900 F, won't scale under 1250 F. Reflective parts bounce back up to 80% of radiant heat, remain strong.

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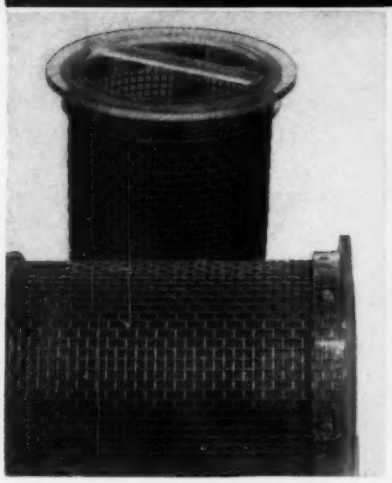

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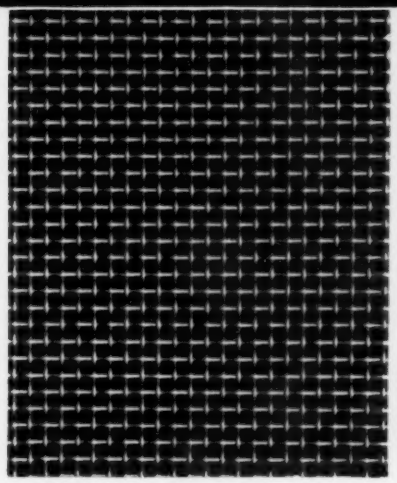

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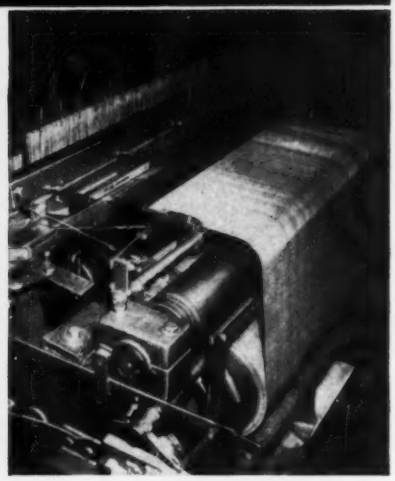

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Refer to our technical data sheets in CHEMICAL ENGINEERING CATALOG, Page 185

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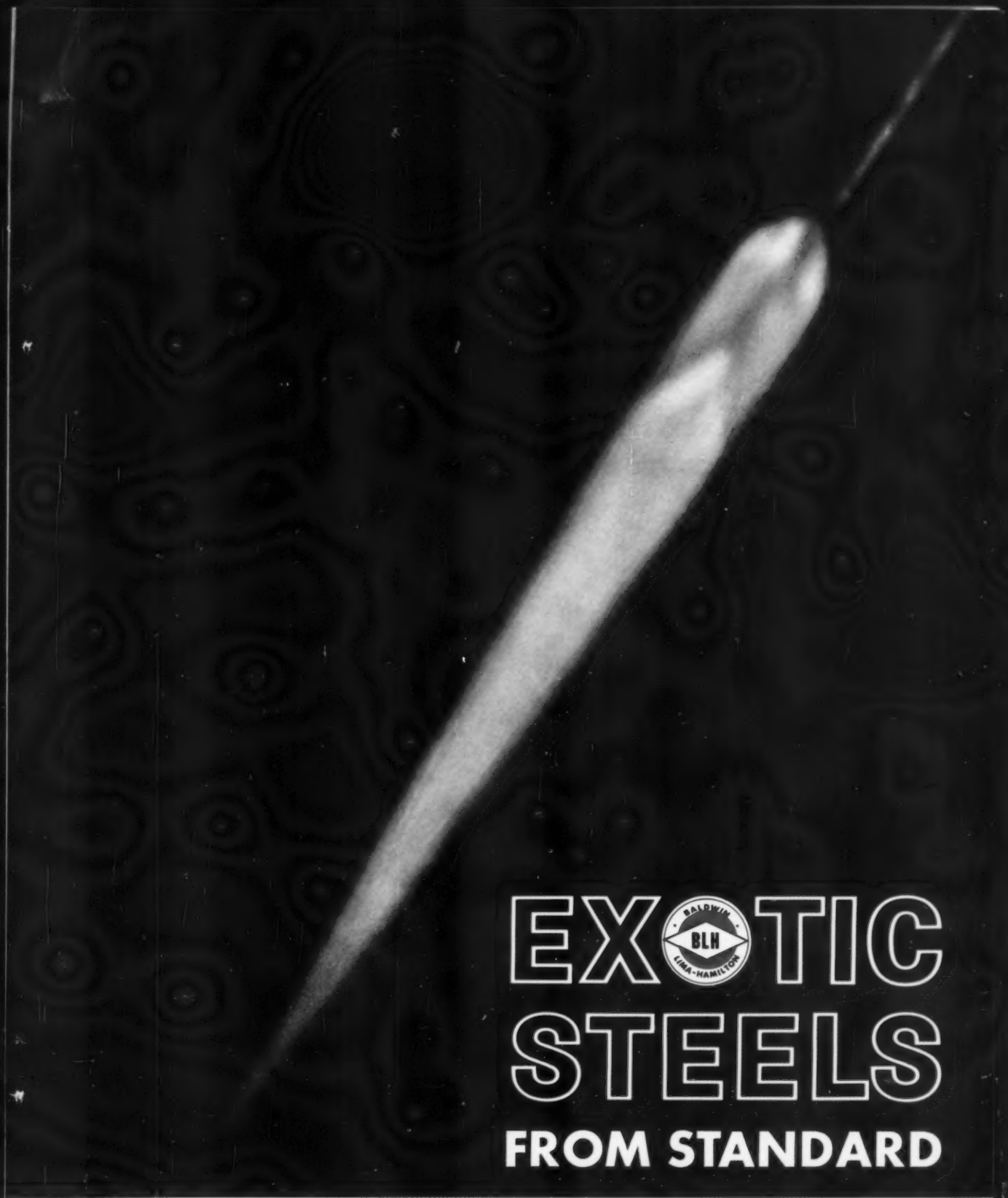

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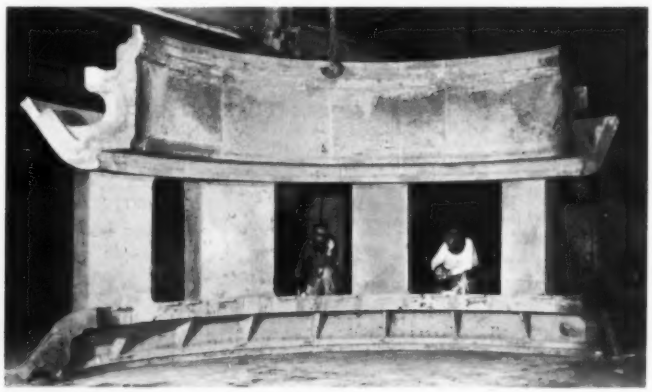

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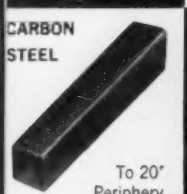

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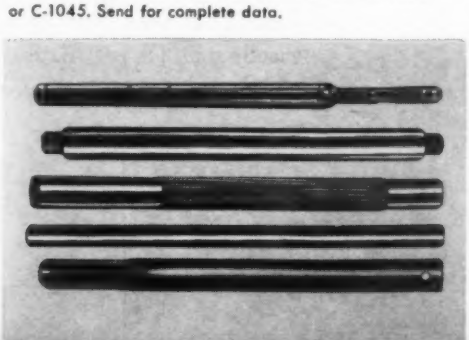

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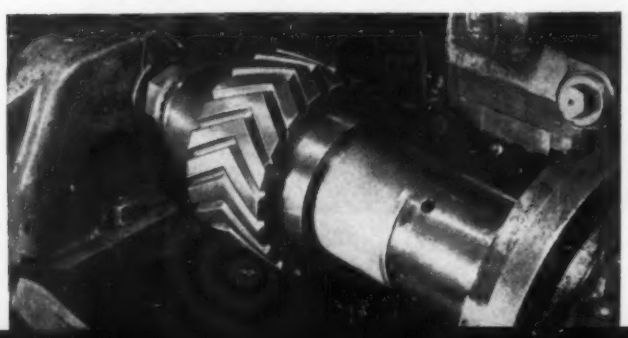

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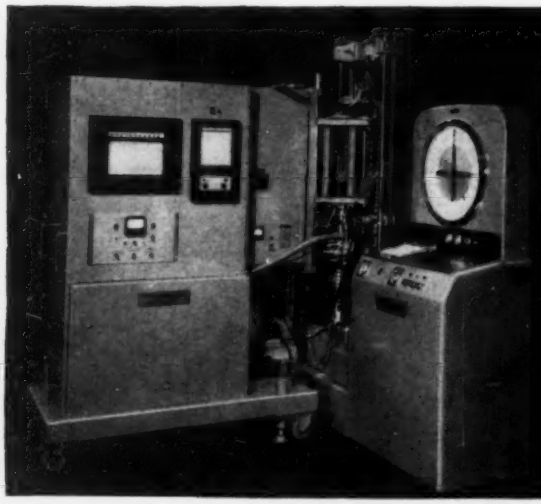

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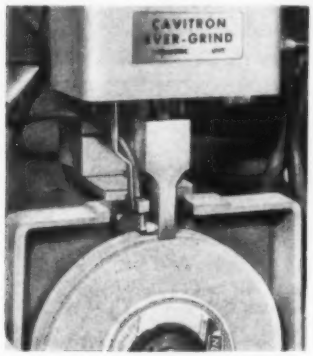
Tooling

Ultrasonics Prevent Loading of Grinding Wheels

The "Cavitron Ever-Grind" unit reduces excessive loading of the wheel, thus minimizing frequent dressing and downtime. Because buildup of particles in the open abrasive structure is



prevented, finer and harder grinding wheels can be used. The result is a finer surface finish and greater dimensional accuracy with a minimum of burring and work deterioration. A transducer vibrating at 20,000 cycles per sec. is attached to an aluminum tool positioned close to the grinding wheel. As coolant passes through the tool, thousands of bubbles explode (cavitation), simultaneously cleaning and cooling the wheel. *Cavitron Equipment Corp.*

For further information circle No. 1630

Pre-Alloyed Heavy Metal Powders

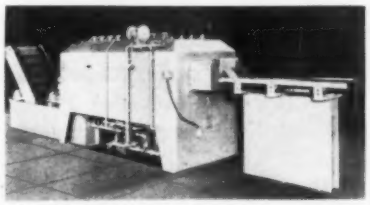
High-density powders – containing tungsten, nickel and copper in any desired composition – are useful as radioactive shields and containers. Since the absorption of x-rays or gamma is proportional to density, these alloys, with densities of around 17 g. per cu.cm., are 1½ times as effective as lead. The product is also used for gyroscope rotors, balancing weights, vibration damping devices, and rocket nozzles. Compared to parts made from mixtures of the three separate powders, this material shows an absence of hard spots, increased machinability and strength, and a more uniform microstructure. *Astro-Alloys.*

For further information circle No. 1631 on literature request card, p. 48-B

Heating

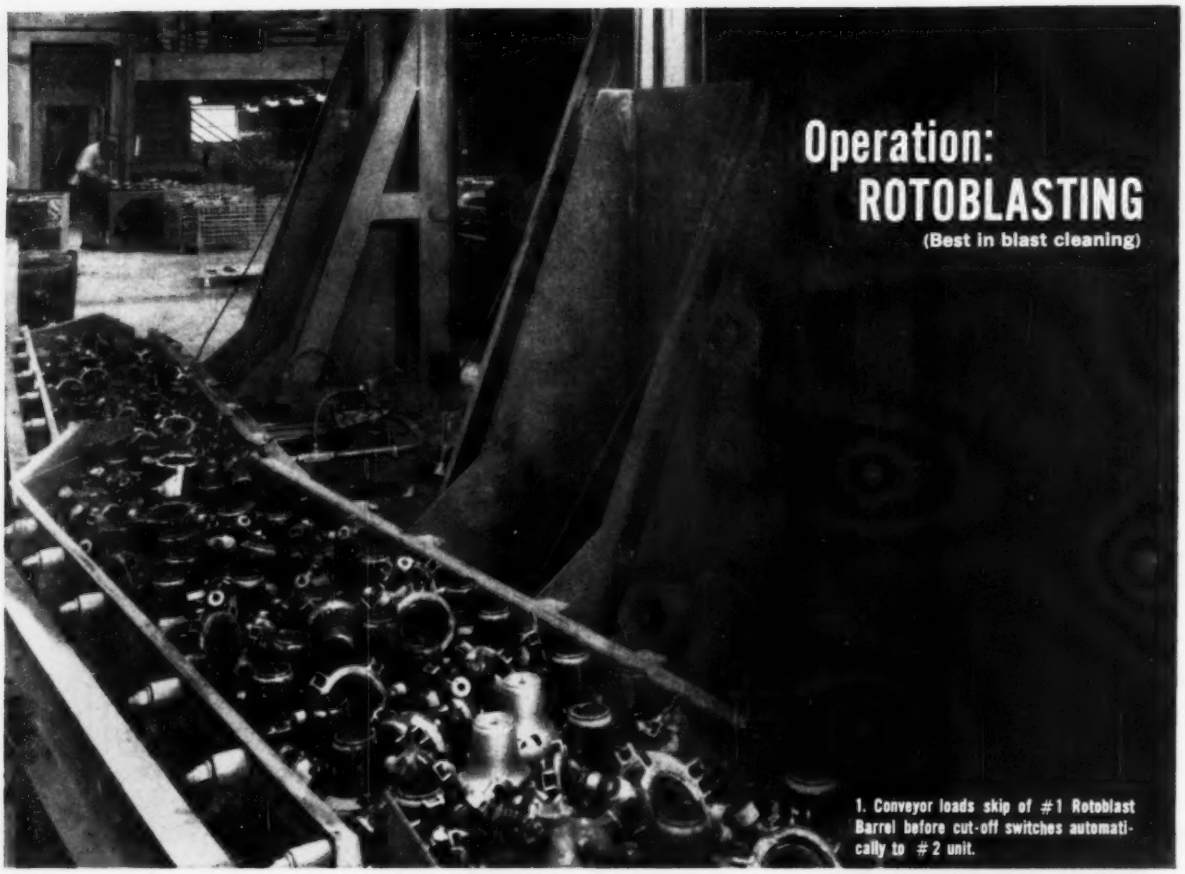
Shaker-Hearth Furnace

A controlled atmosphere heat treating furnace, featuring 100% forced convection heating of the work for uniform heating, is announced by *Ipsen Industries, Inc.* The unit includes a preheat vestibule, a two-zone heating chamber and a conveyorized quench tank. Used for bright hardening, carbonitriding, and light case-carburizing, the furnace operates up



to 1550° F. and has a maximum heating capacity of 1000 lb. per hr. With an automatic hopper feed, it is capable of carrying work through preheat, heating and quenching without further attention by the operator.

Circle No. 1632 on request card, p. 48-B



1. Conveyor loads skip of #1 Rotoblast Barrel before cut-off switches automatically to #2 unit.

Complete automation in blast cleaning!

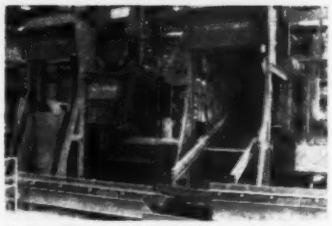
Pangborn Rotoblast removes heavy sand cores and cleans up to 45,000 castings per shift at Neptune Meter!

A new and *completely automatic* Rotoblast operation not only cleans castings in half the time, but a new special separation removes heavy sand cores as well at Neptune Meter Co., Long Island City. The world's largest exclusive manufacturer of meters for liquids, Neptune can now handle 45,000 castings from the molds each shift . . . with just two automated Rotoblast Barrels.

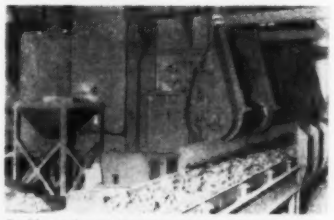
No costly or time-consuming manual lifting, toting or weighing here! Once the button is pressed, the Rotoblast sequence starts and recycles automatically until stopped at the end of the shift!

Whether your installation features automation or batch cleaning, Rotoblast cleaning efficiency can cut *your* operating and manpower costs. Flexibility of installation, ease of maintenance, durable construction—all contribute to lower overall cleaning costs.

Write PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md., Pangborn Canada, Ltd., 47 Shaft Road, Toronto (Rexdale), Canada; or phone district office in Yellow Pages, "Sand Blast Equipment." *Manufacturers of Blast Cleaning, Vibratory Finishing, Dust and Fume Control Equipment—Rotoblast® Steel Shot and Grit©.*



2. Skip fills second unit with exact pre-determined load for cleaning.



3. Cleaned castings move on take-away conveyor to next operation.

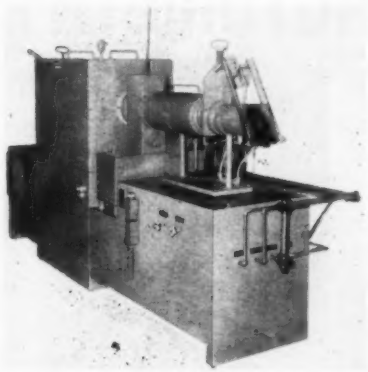
4. Before and after Rotoblasting. Note core sand and rods in uncleaned piece.

Pangborn
OF HAGERSTOWN

Circle 1850 on Page 48-B

Tube Furnace Offers Choice of Quenches

The "Type RDT15-620AC20" furnace has a 6-in. I.D. Inconel muffle, a 20-in. long heat chamber, water-cooled; and a maximum operating temperature of 2000° F. A chute between the heat chamber and the quench permits either an oil quench



or atmosphere cooling. Automatic flame curtains at the entry and discharge doors prevent infiltration of air into the muffle. *Lindberg Engineering Co.*

For further information circle No. 1633 on literature request card, p. 48-B

180-Cycle Induction Power Source

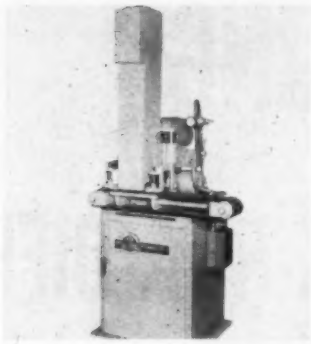
The "Inducto Tri-Line" frequency multiplier fills the gap between conventional motor-generators and 60-cycle line-frequency induction power sources. For production melting operations as well as sintering, hot pressing, graphitizing, and billet heating, 180-cycle power offers the advantages of lower installation and maintenance costs plus improved performance. Pronounced stirring developed by the unit is about 2½ times that of comparable high-frequency induction melting furnaces. Units are available with output capacities from 125 to 700 kw. *Inductotherm Corp.*

For further information circle No. 1634 on literature request card, p. 48-B

Finishing

Automatic Finishing Machines

The "Model JC" abrasive-belt finishing machine was featured by *Acme Mfg. Co.* at the Metal Show in Detroit. The equipment performs flat grinding, deburring and polishing operations on such parts as stampings,

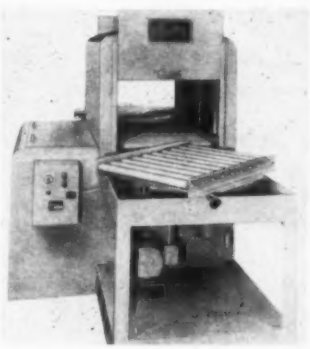


forgings and castings. A motorized conveyor belt carries work under spring-loaded hold-down rollers and the abrasive belt contact wheel. Multiple-head assemblies can be mounted in tandem along one long conveyor belt to perform progressive finishing operations. Features include positive manual or automatic belt tracking, micrometer grind-pressure adjustment, and pneumatic tensioning of the abrasive belt.

For further information circle No. 1635 on literature request card, p. 48-B

Power Spray Washer

A swivel table washer made by *Waukee Engineering Co.* allows parts to be charged or discharged from either side at a 90° angle as well as to the front of the loading table. A locking device prevents the table from moving accidentally. The unit is available in either a single or double end design. Manufactured in stand-

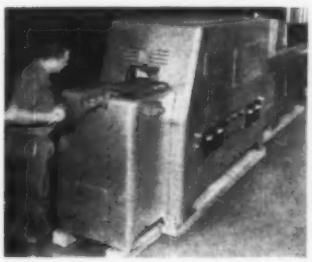


ard sizes up to 30 by 48 by 24 in. to match furnace sizes, the washer features spray nozzles above and below the work, and an automatic wash-cycle timer which shuts off the pump when washing is completed. The equipment offers a choice of heating – gas, steam or electric – and automatic temperature control.

For further information circle No. 1636 on literature request card, p. 48-B

CARL PAULSON, Dir. of R & D reports on new

NO-MUFFLE FURNACE for H. S. Steel



Temperatures to 2350°F (high enough for 18-4-1 H. S. Steels) . . . and fast heat up! Complete atmosphere compatibility (nitrogen, dissociated ammonia, endothermic) and quick stabilization to low dew points! High purity refractory . . . selected after testing 11 different materials! And NO MUFFLE* . . . no muffle expense . . . no muffle sag . . . no muffle replacement costs!

That's the story of C. I. Hayes Model FEC Open Chamber Furnace, designed for the plant that wants greater control and greater versatility in their hardening operations. Shifts from one steel to another (H.S., S.S., High Chrome/High Carbon, Cold Header Stock)

no longer constitute production problems. Output is clean. Secondary grinding and finishing operations can be reduced or eliminated.

Want facts? Write for Data Sheet FEC-1. C. I. Hayes, Inc., 802 Wellington Ave., Cranston 10, R. I.

*Hayes Muffle-type Furnaces are also available, where required.

C. I. HAYES, INC.

Established 1905

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-Master (TM) power controls, induction generators.

Circle 1851 on Page 48-B

NEW THINKING

in instrumentation for

X-RAY DIFFRACTOMETRY

all new
Picker X-ray
Diffraction Equipment
introduces

INNOVATIONS *that simplify operation and improve accuracy*

here's a sampling of some

A monitor-controlled x-ray generator for easy selection and confident reproducibility of exposure factors.

A biplane diffractometer you can use the way you want to: *horizontally* or *vertically*.

A diffractometer that supports its own x-ray tube, specimen and detector for locked-in alignment.

An x-ray tube mounting that lets you adjust take-off angle without disturbing beam-specimen alignment.

A specimen turntable with independent Omega drive to reveal anomalous orientation, thus facilitating single crystal work.

An x-ray tube housing with integral shutters that provide maximum radiation safety.

A diffractometer with unrivalled variety of scanning modes under remote automatic control.

ACA-approved dovetail tracks that make it easy to mount, align and remove cameras and accessories

and

A unique SYNCHRONITOR that coordinates the whole system of components and circuitry that electronically instructs scanning, analyzing, and recording instruments how to function for each scanning mode.

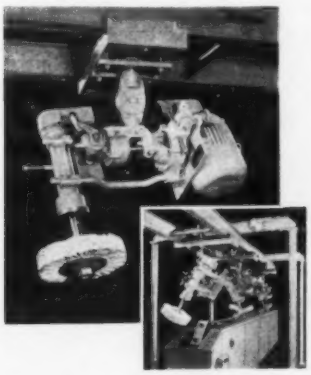
Get the full story *on this remarkable new equipment from your local Picker representative (see 'phone book) or write Picker X-Ray Corporation, White Plains, N.Y.*

if it has to do with RADIATION | it has to do with Picker x-ray

Circle 1852 on Page 48-B

Universal Polishing Heads

In polishing irregular work shapes, full wheel contact may now be achieved with fewer heads using the "Model 052" unit. Overhead mounting provides easier access to the heads and conveyor and simplified cleanup. The unit, with a choice of capacities up to 20 hp., utilizes two fulcrums; this affords a more flexible movement of the work wheel, enabling it to follow closely an irregular shape in two planes. Two simple fulcrum adjustments determine the degree of



angularity and accurately position the wheel. An automatic motor mounting adjustment keeps proper tension on the drive belt at all times. *Murray-Way Corp.*

For further information circle No. 1637

Automatically Controlled Rectifiers

For high-current, low-voltage applications such as anodizing, plating, and electrochemical machining, *Hanson-Van Winkle-Munning Co.* is offering a line of silicon rectifiers ranging in power from 1000 to 10,000 amp. and 6 to 100v. Transistorized controls provide either current or voltage stabilization for automatic control of rectifier output. The control can be made proportional to line speed, temperature, or other production variables; it also has an automatic current-limiting feature which prevents the unit from being overloaded under normal overload and short circuit conditions.

For further information circle No. 1638 on literature request card, p. 48-B

Welding

Welding Thin-Gage Metal

The "Model SA-200" welding system from *Westinghouse* includes a 200-amp. silicon diode rectifier power source, a compact wire-drive system with a wide feed range, and a straight-through welding torch. The wire-drive system has a range of 90 to 424 ipm. with standard gearing, and can be modified to provide speeds up to 1170 ipm. The straight-through torch weighs only 22 oz. and accommodates wire sizes in mild or stainless steel from 0.025 to 0.047 in. The torch, rated 100% duty cycle at 200

amp., comes with a 15-ft. welding cable, gas hose and electric control cable.

For further information circle No. 1639

Short Arc Welding

In short-arc welding, many short circuits per second permit deposition of electrode metal as tiny drops instead of the usual spray. It provides a uniform burnoff rate and pinpoint control of arc heat, producing quality welds on all sheet-metal thicknesses without burnthrough. The "Sigma SWM-14" unit includes a 200-amp. power supply with variable voltage and inductance controls; a 14-oz., 200-amp. torch; and a compact wire-feed control unit with centrifugal governor. Wire sizes accommodated are 0.030, 0.035 and 0.045 in. *Linde.*

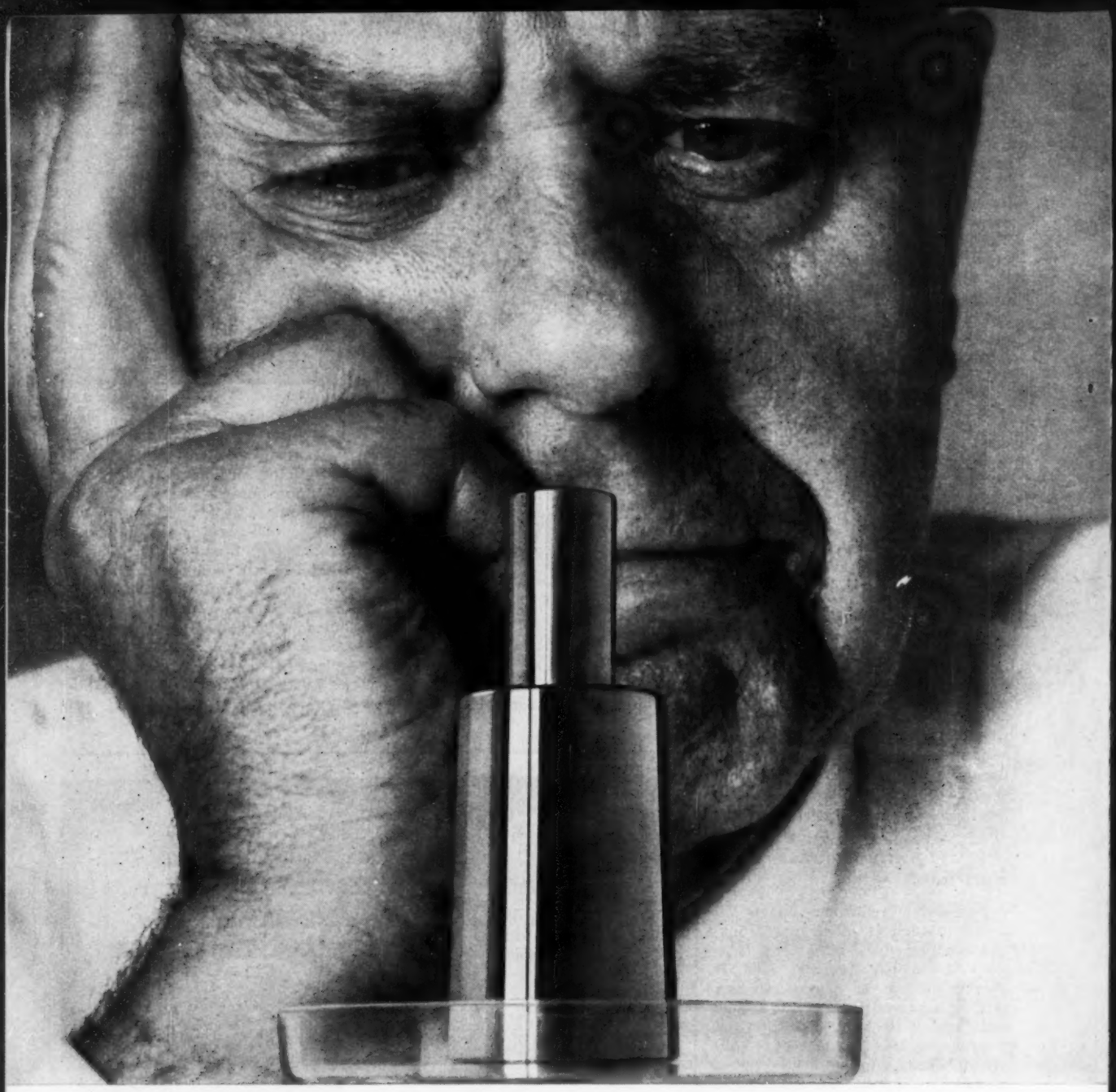
For further information circle No. 1640

PSC *fabricated alloy*
FURNACE TUBES & RETORTS

SAVE YOU MONEY — Since we are able to work to lighter sections, PSC all-sheet alloy equipment costs you less than cast units. This light-wall construction saves in freight and handling time as well as in furnace time and fuel. Let us also save you money by repairing your radiant tubes, retorts and inner covers.

THE PRESSED STEEL CO. • Wilkes-Barre, Pa.

Circle 1853 on Page 48-B



RELAX!

It won't grow—or shrink or wear—it's Graph-Mo®—In twelve years of use, the master tapered plug gage in the picture above changed less than 10 millionths of an inch. That's stability—the kind of stability you get with Graph-Mo, one of the family of Timken® tool steels. ■ But stability is only part of the story when you use Graph-Mo. ■ Users report that Graph-Mo *outwears ordinary tool steels three to one.* It contains free graphite particles and diamond-hard carbides in its structure. ■ And users cut machining time and production costs. Graph-Mo is an oil hardening steel that machines faster and easier than ordinary tool steels. ■ You pay no more for all these Graph-Mo advantages. It costs no more than ordinary oil hardening tool steels. There is only one Graph-Mo and the Timken Company makes it. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

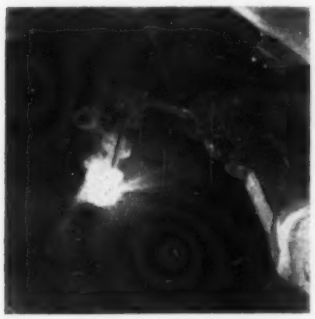
TIMKEN FINE ALLOY STEEL

TIMKEN GRAPHITIC STEELS ARE AVAILABLE FROM STEEL SERVICE CENTERS IN MORE THAN 40 CITIES IN THE UNITED STATES AND CANADA

Circle 1854 on Page 48-B

Tungsten Carbide Hardfacing

For hardfacing large pieces on which gas application is not feasible, use of a solid-core "Kenface KT-200" arc rod should be considered. The rod is composed of a solid tungsten carbide core surrounded by a steel sheath and a coating that permits smooth deposition. The deposit has low porosity and a minimum of heat checking. Suitable for either bead or wash pass application, the rod can



be applied by either a-c. or d-c. reverse polarity (160 to 200 amp., 16 to 20 v.) welding. Rockwell hardness of a deposit ranges from C-58 to 63. Coverage is 25 sq. in. per lb. of rod per ⅛ in. of coating thickness. *Kennametal Inc.*

For further information circle No. 1641

Multiple Spot Welding

A power pack for high-production spot welding of small parts has been introduced by *Ampower Products.* Composed of two (or more) high-output, water-cooled transformers, the compact unit offers single-cycle operation of one or more spots in rapid sequence. Air-actuated timing controls have 100 amp. contactors and can operate the transformers in single sequence or in pairs. The buildup of welding tip pressure triggers the first timer, which in turn triggers the second one, and so on. Power supply required is 220 v., 60 cycle, single phase; maximum output is 10 kva. per transformer.

For further information circle No. 1642 on literature request card, p. 48-B

Coated Electrode for Aluminum Welding

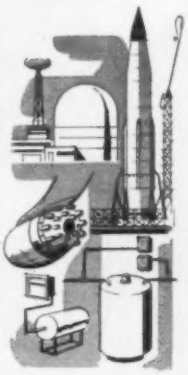
For all-position welding (direct current, reverse polarity) of aluminum plate, sheet and castings, *Air Reduction Sales Co.* is offering a new aluminum electrode with an extruded coating (A.W.S. Grade Al-43). The "Airco 43" electrode operates with a

Specially processed wire for use in SHEATHED THERMOCOUPLE ASSEMBLIES

Chromel-Alumel®

SPECIFICATION 3G-220 THERMOCOUPLE ALLOYS

One good reason for the fine reliability of sheathed thermocouple assemblies—in heat treating and chemical processing applications, jet engines, missiles, and nuclear reactors—has been the development of Hoskins Specification 3G-220 Chromel and Alumel wire. It's a special grade of material produced specifically for swaged, rolled or drawn sheathed unit construction. And all that's required to overcome adverse effects of such cold-working operations on its emf properties is a simple, quick heat treatment after fabrication.



A brand new 36-page catalog-manual contains detailed technical data on this and the complete "family" of time-tested Chromel-Alumel thermocouple, lead-wire, and mechanical grade alloys. Want a copy?

**The words "Chromel" and "Alumel" are registered trademarks of*

HOSKINS MANUFACTURING COMPANY

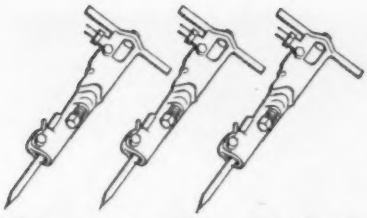
4445 Lawton Avenue • Detroit 8, Michigan • TYler 5-2860

In Canada: Hoskins Alloys of Canada, Ltd., Toronto, Ontario

Producers of Custom-Quality Electrical Resistance, Resistor and Thermoelectric Alloys Since 1908

Circle 1855 on Page 48-B

The Porter Alloyist delivers the right alloy IN THE SPOTS THAT COUNT

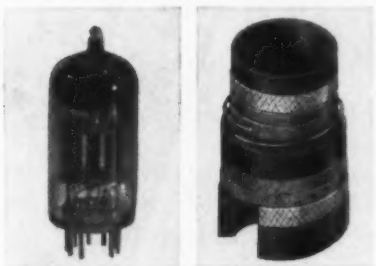


There can be no compromise in metals for those tougher, tool-killing jobs. That's why the Porter Alloyist recommends Grade D phosphor bronze for the rifle nut in air hammers . . . the critical part of the tool that absorbs hundreds of vibrations a minute at high impact pressure. Produced at a special temper, this alloy has the required toughness and durability to do the job and to help keep tool maintenance costs low.

THE PORTER ALLOYIST IS A SPECIALIST IN A WIDE RANGE OF SPECIAL METALS

Porter's Riverside-Alloy Metal Division is your single reliable source for specialty alloys in 8 basic groups of wire, rod and strip . . . phosphor bronze, nickel silver, cupro nickel, brass, stainless steel, nickel, Monel and Inconel.

Ask for a free copy of "Alloys for Industry" describing our wide range of specialty alloys. Write H. K. Porter Company, Inc., Riverside-Alloy Metal Division, Riverside, N.J. Or contact our sales offices in Hartford, Chicago, East Orange, Atlanta, Cleveland, Detroit, Cincinnati, Los Angeles and Rochester.



PORTER nickel wire is used extensively in vacuum tubes and in other components for the electronics industry.

PORTER carbon steel wire reinforces hose for air hammers and other industrial equipment.

PORTER

RIVERSIDE-ALLOY METAL DIVISION
H. K. PORTER COMPANY, INC.
Circle 1856 on Page 48-B

quiet arc providing a dense, low-spatter deposit. Welds develop yield strengths of 28,000 psi. Airco 43 is available in two sizes – ⅛ in. diameter by 14 in. long, and 5/32 in. diameter by 16 in. long – and is ideal for repairing cracks, building up worn parts, cladding, and for production welding.

For further information circle No. 1643

Testing

Mobile 150-Curie Unit

Ideal for high-production radiography of heavy sections in foundries and fabricating plants, the "Model 520" cobalt unit requires an exposure time only 7% of that needed with a

10-curie source. Designed for directional inspection, it can be adapted for panoramic use by removing a plug in the source container and adding guide tubes. The balanced source-head can be swiveled downward (45°) from a vertical position and can be locked at any angle. *Picker X-Ray Corp.*

For further information circle No. 1644 on literature request card, p. 48-B

Strain Gage Systems

A comprehensive line of instrumentation for strain gage, transducer, and calibrating systems has been introduced by *Baldwin-Lima-Hamilton Corp.* The line – to be used with SR-4 and related strain-gage equipment – includes precision indicators, digital indicators, pointer-indicators, circular chart recorders, universal digital transducer units, multipoint scanner recorders, switching and balancing units, as well as manual and automatic null-balance digital calibration equipment. The complete instrument line will afford single-source responsibility for complicated transducer systems required for any force-measuring application.

For further information circle No. 1645

Precision Measuring Tool

With the "Die-Wear" microscope, the exact amount of metal which must be ground away to resharpen edges can be quickly determined. The instrument, capable of measuring die wear over a range of 0.020 in. to an accuracy of ±0.0005 in., provides

an inspection technique which increases die life and reduces production and maintenance costs. It can also be used to measure bevels, burrs, and fillets. *Bausch & Lomb.*

For further information circle No. 1646

Casting

Furnace Gas Analyzer

The "Model 1010" will analyze atmospheres in heat treating and annealing furnaces, in blast and open-hearth furnaces and in gas generators. The unit provides "direct-trend" recording of up to eight components, including hydrogen, oxygen, nitrogen, CO, CO_2, methane, and H_2O. A complete analysis is provided every 5 min., and automatic standardization before each cycle assures utmost reliability. *Research and Control Instruments, Inc.*

For further information circle No. 1647

Parts

Wide Flange Beams

Heat treated steel shapes have about three times the yield strength of structural carbon steel. Design engineers can either add this strength to their structures without increasing weight, or they can reduce the weight that would be required in a carbon steel structure to support a given load. Wide-flange rolled beams (6 to 8 in.) in USS "T-1" and "T-1" Type A are being used in the manufacture of truck trailers, crane beams, TV towers, and railroad cars. Heat treated shapes in "HY-80" armor steel are also utilized in submarine hulls. *U.S. Steel Corp.*

For further information circle No. 1648

How to reduce furnace heat loss

Vertical pit-type carburizing furnace (9' x 24') lined with a refractory insulating castable made with LUMNITE cement. Furnace temperature 1800°F. Badall Engineering & Manufacturing Co., Hammond, Ind. Castable used: "Kast-O-Lite," product of A. P. Green Fire Brick Co., Mexico, Mo.

Refractory insulating concrete, made with LUMNITE calcium-aluminate cement, is being specified for linings in many types of industrial furnaces. It helps trim fuel costs by reducing heat loss and increasing heat storage. This helps shorten heating-cooling cycles and provides closer temperature control. In addition, the smooth, jointless concrete surface reduces air infiltration.

Construction with refractory concrete is fast, easy, economical. Linings can be cast in place, troweled or "gunited." Service strength is reached in 24 hours.

For convenience, manufacturers of refractories offer castables bonded with LUMNITE cement – packaged mixtures ready for use with just the addition of water. For more information, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

"USS," "Atlas" and "Lumnite" are registered trademarks L-193

Universal Atlas Cement
Division of
United States Steel

OFFICES: Albany • Birmingham • Boston • Chicago • Dayton • Kansas City • Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh • St. Louis • Waco

Circle 1857 on Page 48-B

Now...a low-cost Nitride-Bonded Silicon Carbide!

CRYSTOLON* "63"

Now, the best-performing silicon carbide refractory is available at a realistic price! Brand-new CRYSTOLON "63" permits the use of a cost-saving nitride-bonded silicon carbide refractory for hundreds of applications.

Produced by an exclusive Norton process, CRYSTOLON "63" silicon carbide provides all the superior properties of nitride-bonded silicon carbide at a *new low cost!* It has high thermal conductivity, excellent heat shock and wear resistance, and good resistance to most corrosive liquids. In extensive tests, it not only showed excellent resistance to "wetting" by molten non-ferrous metals (aluminum, magnesium, zinc, lead and others) but also to fused salts, such as cryolite!

CRYSTOLON "63" refractories can well mean a vast improvement in many of today's metal melting and transfer operations . . . new efficiency and economy *throughout* operations such as *yours*. Get complete details now! Write NORTON COMPANY, Refractories Division, 330 New Bond Street, Worcester 6, Massachusetts.

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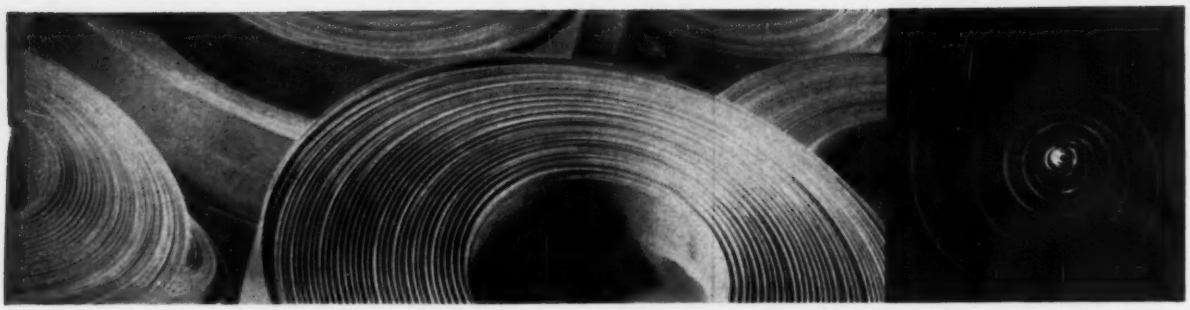
NORTON
REFRACTORIES
Engineered... Rx ...Prescribed

75 years of
Making better products
...to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — BEHR-MANNING DIVISION: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

Circle 1858 on Page 48-B



How they're using

Wallace Barnes Cold-rolled Specialty Steels

1. *In Three Drawing Stations*

The part shown in illustration one was made from .59 – .74% carbon steel in three drawing stations. From .70 – .80% carbon, this piece should have four or five drawing stations. The piece could be made from .90 – 1.05% carbon, but would require seven drawing stations with fully annealed steel.

2. *Blanked on 45° Angle*

The stamping shown in the second illustration was made from .70 – .80% carbon spring steel. It was blanked and pierced on a 45° angle, with small holes pierced to prevent fracture in later forming and bending. It was then given severe secondary forming. The small tab shows "orange peel" and probable fracture would occur if the part were formed from .90 – 1.05% carbon.

3. *All Flanging One Operation*

Our third part is a gun stamping made from .70 – .80% carbon with a sharp bend with the grain in one stroke of the press. Higher carbon will fracture due to its less ductile qualities.

4. *Thirteen Steps Progressive*

The fastener shown in the fourth illustration was made from the .59 – .74% carbon steel, the only spring steel which would take the bends and draws to which it is subjected here. All the higher carbon steels were rejected because they failed under the cold-work necessary to produce the two small extrusions. It took seven reductions to bring these extrusions within tolerance. There were thirteen steps total in the progressive die.

These examples show how proper steel selection may save operations and insure satisfactory performance. Among the many sizes and types of Wallace Barnes cold-rolled specialty steels is the right one for your application.

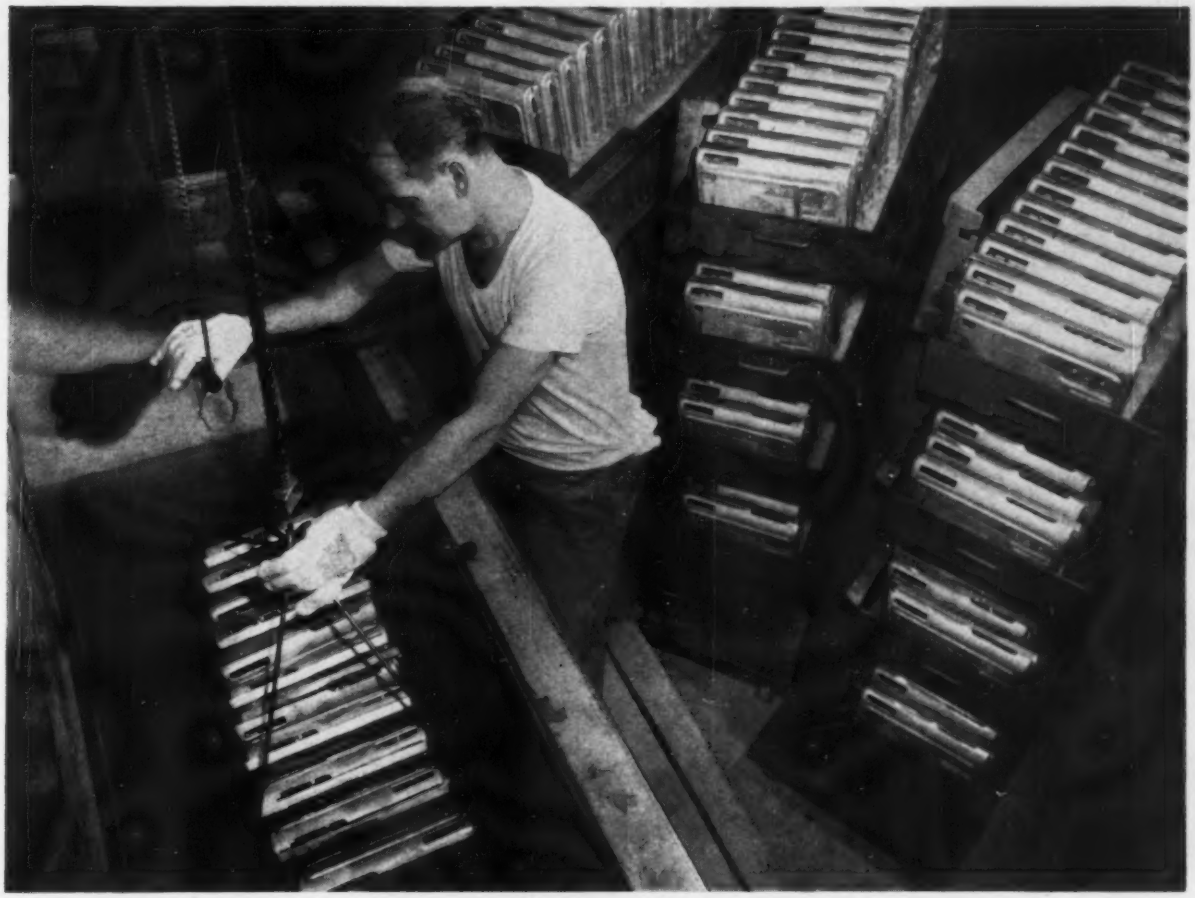
Send for brochure illustrating various types of products made from Wallace Barnes Specialty Steels.

Wallace Barnes Steel Division

Bristol, Connecticut

Associated Spring Corporation

Circle 1859 on Page 48-B



HOW VOICEWRITER CUTS DEGREASING TIME UP TO 50%

. . . and cleans parts spotlessly every time

Nearly every metal part on an Edison Voicewriter requires machining. "Since absolutely clean metal components are essential to the smooth operation of these fine machines," says Robert Spears, Voicewriter's factory superintendent, "we have to use a dependable degreasing solvent." Nialk® TRICHLORethylene is the one they've used for years.

"It's stable and safe," Mr. Spears says, "and certainly economical and efficient." He explained that only one degreasing in Hooker TRICHLOR is necessary, while many other types of cleaners require two. Degreasing time is perhaps one-half what it would be with another type of cleaner.

Even more important, according to Mr. Spears, is that Hooker TRICHLOR removes all soils *definitely*. There are no hidden pockets of dirt or grease to be picked up as rejects by inspectors or at the paint shop.

A specific property of Hooker TRICHLOR that particularly benefits Voicewriter production is its unique neutral stabilizer system. Since virtually all the metal parts on the Voicewriter are aluminum, it's important to see to it that the solvent doesn't turn acid. Hooker TRICHLOR satifies that requirement particularly well because the stabilizer has *psp*—permanent staying power.

Both degreasers at the Voicewriter plant are *original* equipment, indicating that the use of Hooker TRICHLOR has had no deleterious effect on the degreasers. One degreaser has been in service 20 years, the other 15 years—with no replacement needed or anticipated.

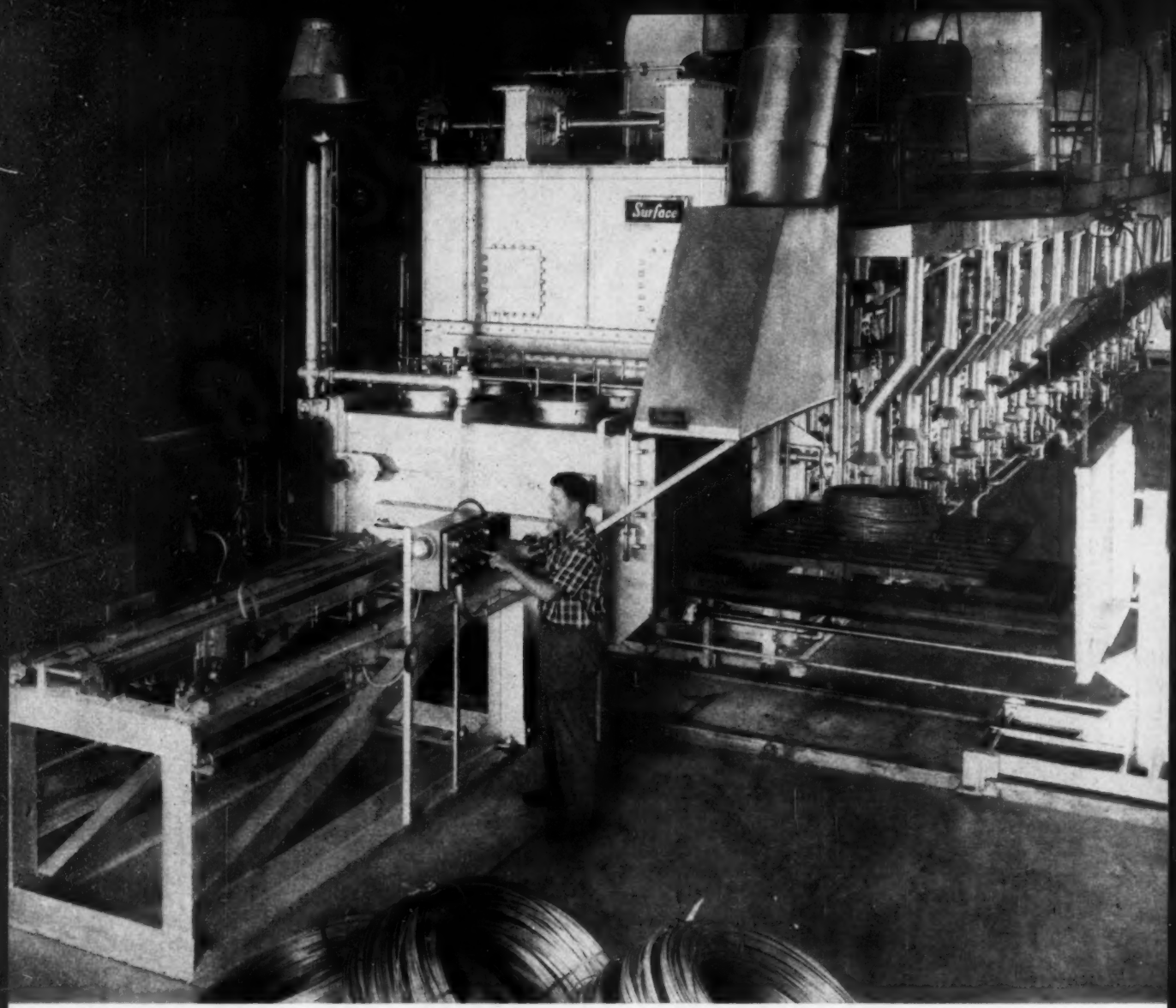
Whatever your metal, whatever your degreasing job, you can solve your cleaning problem with Nialk TRICHLOR. See your chemical distributor or drop us a line. Hooker experience is yours for the asking.

HOOKER CHEMICAL CORPORATION

411 UNION STREET, NIAGARA FALLS, NEW YORK

HOOKER CHEMICALS PLASTICS

Sales offices: Buffalo, Chicago, Detroit, Los Angeles, New York, Niagara Falls, Philadelphia, Tacoma, Worcester, Mass. *In Canada:* Hooker Chemicals Limited, North Vancouver, B.C.



Wire inventories reduced by 80% and delivery time cut from months to days

That's the report of the Butcher and Hart Manufacturing Company of Altoona, Pennsylvania. Manufacturers of wire fasteners, Butcher and Hart installed a wire drawing line and a Surface continuous annealing furnace so they could fabricate their own wire and insure its workability for drawing and cold heading operations.

The 100 foot furnace is used to spheroidize the wire between drawings and control carbon for subsequent operations. Only two men operate the entire drawing and annealing line. The consistent and accurate system is composed of the air tight furnace, economical gas generation, and automatic control of carbon content.

The continuous line furnace has carburizing, carbonitriding, skin recovery, annealing, and spheroidizing capabilities.

Write for information: 2377 Dorr St., Toledo 1, Ohio. In Canada: 2490 Bloor St., West, Toronto.

SURFACE

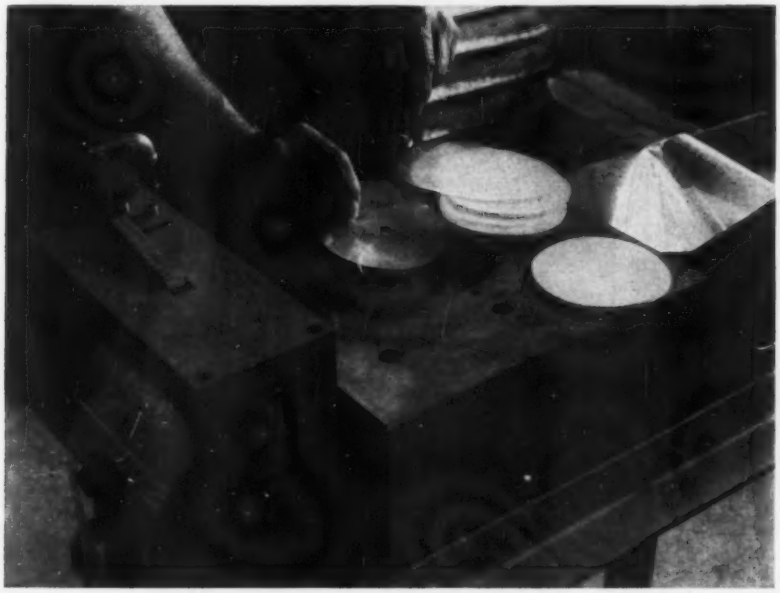
SURFACE COMBUSTION, Toledo 1, Ohio/ a division of Midland-Ross Corporation

Circle 1861 on Page 48-B

for Strength
. . . Economy
. . . Versatility

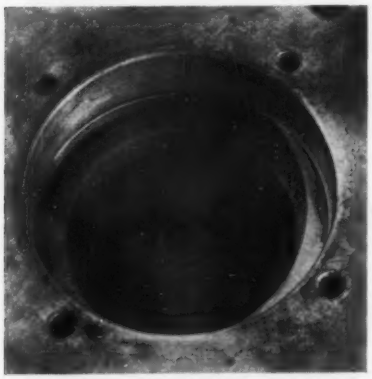
Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation



Seals for jet engine starter cartridges blanked with Lehigh H

The job was tricky. It involved cutting 6-in. circles from .002 in. Mylar, a plastic material used for vapor seals in jet engine starter cartridge parts because of its high strength and resistance to tearing. Bethlehem Lehigh H tool steel was selected by Seymour Manufacturing Co., Seymour, Indiana, who designed and built the die for Amoco Chemicals Corp. Lehigh H was a wise choice. The die, made to extremely close tolerances, blanked the material cleanly, and produced nearly 140,000 pieces before slight redressing was required.



Lehigh H (AISI D-2) is our easy-machining high-carbon, high-chrome grade of air-hardening tool steel. It has high compressive strength, deep hardenability, and excellent resistance to wear.

Lehigh H has wide range of metal working uses

Because of its ideal properties, Lehigh H is used for blanking, forming, punching, shearing, bending, and other tool and die jobs. It's frequently used for rotary slitting cutters, wearing plates, and thread-roller dies.

Good things happen when you put Lehigh H on the job. Your local Bethlehem tool steel distributor can make prompt delivery.

Call him today for complete details.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

"Wear-In" of Tools Must Be Handled with Care

The initial use of new tools is the most critical period of operation. For example, during the "wear-in" period, the working surfaces of a drawing die and its mating punch may gall or "pick-up" portions of the metal being formed. This condition must be detected soon after it occurs, then removed promptly by hand stoning, to prevent further surface damage to the tools. If it is not detected and removed, heavy scoring and seizing may occur, producing not only short tool life but defective parts as well.

Obviously, the use of an effective lubricant will decrease "wear-in" problems, but even the best lubrication practice may not be sufficient protection on many operations. For example, a combination of tools and lubricant which performs well in processing soft steel may be troublesome in working stainless stock. Close attention to such tools during "wear-in" will delay the "wear-out" period.

Air-4 Tool Steel Machines with Ease.

Bethlehem Air-4 is a medium-alloy tool steel which hardens in air at 1550 F. It has excellent free-machining characteristics, due to a carefully controlled addition of lead. Air-4 also has plenty of wear-resistance, toughness, and deep-hardening properties. It can also be heat-treated without running any danger of cracking.

Circle 1862 on Page 48-B

HEATING or MELTING LARGE VOLUMES of METAL?

NEW TRI-LINE* 180-Cycle Static Frequency Multipliers

extend induction power to a wider range of applications—often at lower cost.

If your production involves large-scale heating or melting, it will pay you to investigate the cost and performance advantages of Inducto Tri-Line 180-Cycle Static Frequency Multipliers. These medium-frequency units fill the gap between Inductotherm high-frequency and Inductotherm Linemelt low-frequency heating and melting equipment. In a wide range of melting, sintering, hot-pressing and graphitizing applications, they offer some unusual economies.

MEET CHANGING LOAD CONDITIONS. The Tri-Line's special transformers and controls, produce 180-cycle current from a balanced 60-cycle, 3-phase input with remarkable flexibility of output to meet changing load conditions.

SUPERIOR STIRRING—INCREASED PENETRATION. Tri-Line units generate stirring forces about 2½ times those of comparable high-frequency induction melting furnaces. You can now maintain the proper amount of stirring in large furnaces to assist in formulating many alloys containing metals of widely varying densities. Also, the increased penetration of 180-cycle power assures improved performance in heating relatively large diameter billets and dies.

*Trademark

CONVENIENT, SAFE OPERATION. Overloads cause no damage. Simple, virtually automatic operation is quickly learned by unskilled personnel.

GET FULL DETAILS. Inducto Tri-Line Multipliers are available with Kw output capacities, furnaces, heating coils and accessories to suit any medium-frequency application. For full information regarding efficiencies and economies in your particular job, ask to have an Inducto Field Engineer call.

Inductotherm Corp., 10 Indel Avenue, Rancocas, N. J.

STEEL SHELL FURNACES, available with any Tri-Line installation, offer significant improvements in rigidity and vibration resistance to greatly prolong lining life. In the illustration, pure nickel is being poured from a 5,000 pound steel shell furnace powered by a 500 Kw Inducto Tri-Line installation at Seaway Nickel Corp., N. Tonawanda, N. Y.

INDUCTOTHERM

Subsidiary for 60-cycle melting equipment—INDUCTOTHERM LINEMELT CORP.

Circle 1863 on Page 49-B

NEW LITERATURE

Steel

1651. Free-Machining Stainless

Universal Cyclops Steel Corp. has published brochure "Uniloy 303MA" which tells of increased production and higher quality of parts machined from this alloy.

1652. Cb-Treated Steel

Columbium-treated carbon steel cuts deadweight 10% in most applications. Available in yields strengths from 45,000 to 60,000 psi. From *Great Lakes Steel Div.*

1653. Steel Design

Four papers which discuss advances in strength levels and design applications of constructional steels, have been published in a 59-p. brochure, "New Concepts in Steel Design and Engineering". *U.S. Steel Corp.*

1654. Alloy Steels

Bethlehem Steel Co. will send "Quick Facts About Alloy Steels", a fundamental treatment of ferrous metallurgy.

1655. Steel Springs

Sandvik Steel, Inc. has information on line of steel springs which give extraordinary fatigue life.

1656. Nickel Steels

When you design, order, or use heavily stressed machine components, consider nickel alloy steels. *International Nickel Co.* has helpful engineering data.

1657. PH Stainless Steels

These steels offer adequate strength and better corrosion resistance than the hardenable grades of chromium stainless. Details from *Republic Steel Corp.*

1658. Cryogenic Service

27-p. booklet "Steels for the Containment of Liquefied Gas" has been issued by *International Nickel Co.*

1659. Strip Mill Products

80-p. reference book spells out the basic information needed to intelligently understand and order strip steel, spring steel, shim steel, electrogalvanized strip steel and flat wire products. *Mill Strip Products Co.*

1660. Stainless Steel Wire

Brochure published by *American Steel and Wire Div.* tells how stainless steel wire is produced; includes application and mechanical property data.

1661. Spring Steels

You can get spring steels in wider widths and in any thickness from *Uddeholm Co.* Catalog-stock list available.

Nonferrous

1662. Platinum Metals

Platinum metals have a superior combination of properties — resistance to high temperatures, exceptional resistance and catalytic action. Bulletin P-6 tells the story. *J. Bishop & Co.*

1663. Tin-Lined Copper

Composite tube combines corrosion resistance and malleability of tin with the strength and ductility of copper. Information about uses of tin in U.S. industry contained in brochure prepared by *Malayan Tin Bureau.*

1664. Specialty Alloys

Leaflet "Alloys for Industry" describes wide range of specialty alloys, including phosphor bronze, nickel silver, cupronickel, brass, stainless steel, nickel, Monel and Inconel in wire, rod and strip. *Riverside-Alloy Div.*

1665. Stock Catalog

290 pages of stock information on nonferrous and stainless steel mill products. Latest government and society specifications included. Data from *Meier Brass & Aluminum Co.*

1666. Rare-Earth Metals

The Lunex Co. will send pamphlet describing the properties of high-purity rare-earth metals including lanthanum, yttrium and gadolinium.

1667. Conductivity Rating

8-p. bulletin provides a rapid check list for electrical conductivity ratings of 56 copper alloys. *Bridgeport Brass Co.*

1668. Gadolinium Metal

Data sheet from *Nuclear Corp. of America* presents physical, electrical, magnetic and mechanical property information on gadolinium.

1669. Ultra-Pure Metals

Union Carbide Metals Co. will send pamphlet discussing columbium, tantalum and vanadium ingots made by a new vacuum process — electron beam melting.

1670. Impact Extrusions

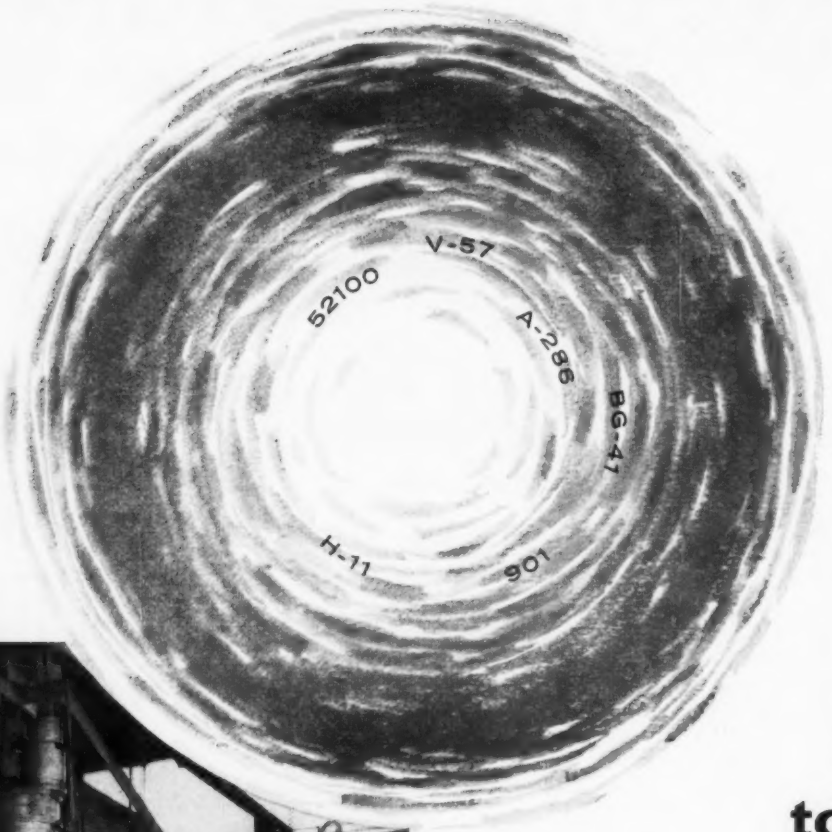
Engineering manual No. FM-3019 discusses impact extrusions in aluminum, copper and steel alloys. *Mueller Brass Co.*

1671. Aluminum Casting Alloy

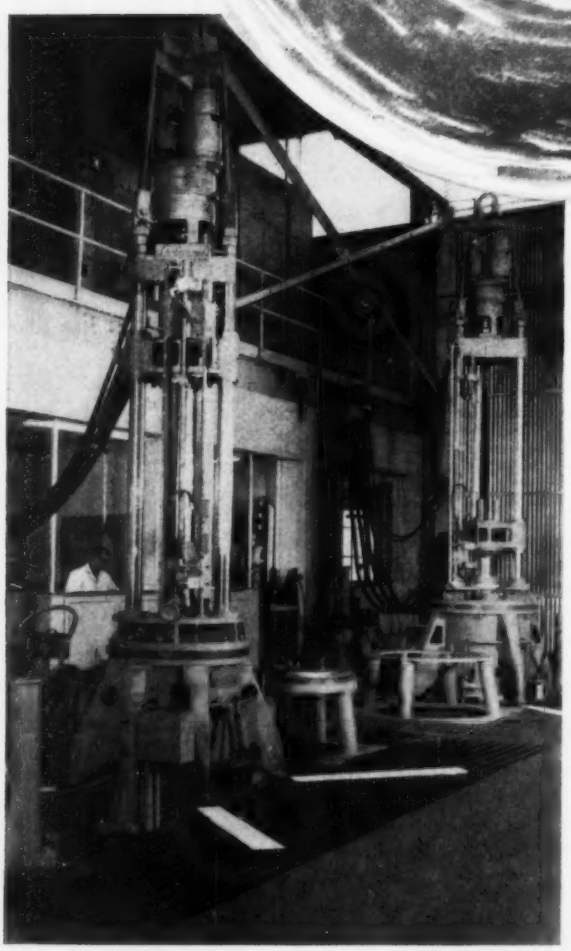
Bulletin 103R5, entitled "Tenzaloy, Self-Aging Aluminum Casting Alloy" has been prepared by *Federated Metals Div.*

Circle appropriate number on Reply Card, p. 48-B

AT LATROBE . . . PROGRESS HAS THE GREEN LIGHT



jet age roars to new horizons



PROGRESS MOVES FORWARD! CAPACITY MORE THAN DOUBLED! NEW 30" CONSUMABLE ELECTRODE FURNACE JOINS 20" UNIT.

AND supporting this technology is the know-how and experience of Latrobe Steel Company in specialty steel making . . . and its new, dynamic Vac-Arc, furnaces keeping pace with tomorrow's fast moving developments.

Through modern vacuum melting techniques, these specially-engineered furnaces are creating high temperature and high strength alloys to new standards.

At Latrobe Steel . . . progress has the green light. If *you* have a problem in alloy application, we are anxious to help you. Latrobe Steel Company, Latrobe, Pennsylvania.

Metalmasters

Made by . . . *skilled* American labor

LATROBE TOOL / DIE SPECIALTY STEELS

Circle 1864 on Page 48-B

1672. Brass Castings

Folder from *Titan Metal Mfg. Co.* details the advantages of pressure die castings in brass — strong, wear resistant and corrosion resistant.

1673. Ti-8Al-1Mo-1V Alloy

12-p. data memorandum outlines forging and heat treat procedures for the alloy and includes discussion of creep stability and fatigue properties. *Titanium Metals Corp. of America.*

1674. Impact Extrusions

Alcoa has published a 34-page brochure on impact extrusions entitled "Metal in Motion" which details applications and savings possible.

1675. Literature Surveys

The *Cobalt Information Center* has literature surveys on cobalt-nickel coatings and cobalt-nickel alloy properties.

1676. Selection Chart

Seymour Manufacturing Co. is offering an "Alloy Selection Chart" for nickel silver, phosphor bronze, brass, copper, and stainless steel.

1677. Phosphor Bronze

Publication B-38 details the advantages of "Duraflex" phosphor bronze. Finer grain structure provides improved fatigue life, better formability and corrosion resistance. *Anaconda American Brass Co.*

Materials

1678. High-Temperature Data

68-p. booklet covers 23 high-temperature alloys and includes data on properties and performance as well as alloy selection and fabrication information. *Carpenter Steel Co.*

1679. "Powder Metallurgy"

Quarterly publication of the *Metal Powder Industries Federation* (spring-summer 1960) features case histories of electrical applications for powder metallurgy parts.

1680. Rene 41

René 41 is the most dependable alloy in use today in the 1200 to 1800° F. range. Bulletin No. 86 from *Cannon-Muskegon.*

1681. Pyrolytic Graphite

General Electric will send details on pyrolytic graphite which exhibits high strength at temperatures up to 5000° F. and excellent thermal and electrical conductivity.

1682. Refractories

Norton Co. has published information on refractories, including magnesium oxide, zirconia, silicon carbide, titanium diboride, as well as other carbides, nitrides and borides.

1683. Protection Tubes

Folder from *Morganite Inc.* contains data on impervious mullite pyrometer protection tubes as well as combustion and furnace tubes.

1684. Sintered Molybdenum

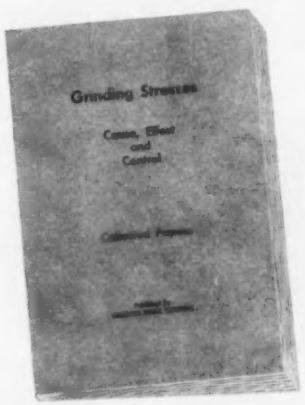
Sylvania Electric Products, Inc. has the full story on molybdenum sintered products for many severe high-temperature applications.

1685. Ceramic Tubes

Ceramic protection tubes for vacuum furnace muffle tubes and radiant heat treating furnace tubes come in diameters up to 10 in. and length up to 72 in.; temperatures up to 3000° F. Information from *McDanel Porcelain Co.*

1650. Grinding Stresses

81-p. booklet "Grinding Stresses: Cause, Effect, and Control" is a collection of articles based on research sponsored by



the Grinding Wheel Institute and the Abrasive Grain Assoc. at Mellon Institute. The booklet proves that fatigue strength is not affected appreciably by most normal grinding operations. It is shown that grinding can actually improve the fatigue strength of a part under certain conditions. *Grinding Wheel Institute.*

1686. Stress-Corrosion Cracking

12-p. booklet from *Haynes Stellite Co.* presents information on the properties and corrosion resistance of Hastelloy F.

1687. High-Temperature Bearings

Booklet issued by *Timken Roller Bearing Co.* discusses three new alloy steels for parts that must withstand rolling contact at temperatures up to 1000° F.

1688. For 2000° F. Service

Electro-Alloys Div. has published bulletin covering "Supertherm", a 26% Cr, 35% Ni alloy for service in the range 1800 to 2300° F.

1689. Corrosion-Resistant Equipment

Bulletin issued by *Heil Process Equipment Corp.* describes company's line of corrosion-resistant equipment, including fume scrubbers, ducts and stacks, fans, tanks and heat exchangers.

1690. High-Temperature Alloy

High strength and hardness from −423 to 1500° F., resistance to oxidation and corrosion, and low creep and relaxation rates combine to make Inconel "X" (Inconel alloy X-750) a superior material for many applications. Bulletin T-38 from *Huntington Alloy Products Div.*

1691. Ceramic Coatings

Norton Co. has prepared booklet describing "Rokide" coating process for protecting vital parts and equipment against temperatures up to 4600° F. and against abrasion, erosion and corrosion.

1692. Hard Carbide Alloys

24-p. outline "Properties of Kennametal" contains detailed description of "Kennametal" and "Kentanium" — physical and mechanical properties as well as suggestions for design. *Kennametal Inc.*

1693. High-Temperature Coatings

Insulative coatings for the protection of missile and rocket equipment are discussed in Brochure No. 500-61 from *Swedlow Inc.*

1694. Alumina Ceramics

Diamonite Products Mfg. Co. has published "Standards of the Alumina Ceramic Manufacturers Association" which contains data on production, design, purchasing, and use of alumina ceramic materials.

1695. Advanced Materials

Carborundum's 8-p. pamphlet "Materials for Advanced Technology" is a data-packed roundup of 12 new products for applications involving resistance to abrasion, chemicals, corrosion, nuclear radiation or high temperatures.

1696. Superalloy Forgings

Brochure on superalloy forgings — Waspaloy, René 41, Astroloy, Udimet 500 and M-252. *Wyman-Gordon Co.*

1697. High-Alloy Castings

Brochure from *Fahralloy Co.* describes stainless and high-temperature alloy precision shell molded or centrifugal castings in sizes ranging from an ounce to 3000 lb.

Nuclear

1698. Nuclear Fuels

8-p. brochure, GEA-6762B, entitled "General Electric Nuclear Fuel" reviews design experience and quality control techniques in fabricating rod-type nuclear fuel elements. *General Electric Co.*

Tooling

1700. High-Energy Rate Forming

"Dynapak" metalworking equipment is used in forging, extruding and metals compaction equipment to reduce production costs, improve metal properties and reduce waste. Information from *General Dynamics.*

1701. Forging Presses

Bulletin 75C from *Ajax Mfg. Co.* covers line of fast operating, well aligned forging presses — built with a solid steel frame in sizes from 300 to 8000-ton capacity.

1702. Colloidal Dispersions

Acheson Colloids Co. has issued a leaflet discussing the capabilities of "Aquadag" colloidal dispersions in many industrial applications.

1703. Composite Powders

Booklet "Metal and Composite Powders" from *Sherritt Gordon Mines Ltd.* discusses clad powders containing metal or nonmetal cores.

1704. Drawing Lubricant

Bulletin 26 from *Swift & Co.* describes "Fleximet S", a multipurpose metallic-base lubricant for dry drawing and hot dip dry-film coating operations.

To request any item listed circle appropriate number on Reply Card, p. 48-B

REMARKABLE NEW PROCESS

...opens way for you to solve critical high-temperature design problems

At 5500°F. cobalt runs like water. Nickel boils. Zinc vaporizes. But tungsten remains solid.

To make this property pay off for you, Sylvania recently put to work its new isostatic pressing and sintering operation. Through this operation, it can produce tungsten or molybdenum ingots up to 10" in diameter and up to 4 feet long. *Sylvania now produces all four* — billets and ingots for forging, electrodes for arc casting, blanks for machining, or machined blanks ready for your use.

Perhaps you've never considered refractory metals as the answer to your needs. But the same properties that solve the problems of throat inserts for rockets and missiles can pay you dividends in piercing points, boring bars, dies, tools and in countless other ways.

Want more facts? Or experienced technical help in proving out your special ideas? Just write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

Circle 1865 on Page 49-B

1705. Tool Steel Heat Treatment

Bethlehem Steel Co. has complete details on short cycle hardening and nitriding of high-carbon, high chromium tool steels.

1706. Tool Steel Guide

A "Steelector" booklet from *Allegheny Ludlum* gives complete data on line of tool steels . . . mechanical property and heat treating information included.

1707. Tool Catalog

480-p. Tool Catalog No. 27 presents a complete display of the *Starrett Co.* line of more than 3500 items.

1708. Graphite Lubricants

"Grapho" colloidal graphite reduces die wear, prevents sticking, gives better metal flow and faster production of aluminum extrusions. Booklet "Biggest Ounce of Protection" from *Grafo Colloids Corp.*

Heating

1710. Thermocouples

48 pages of profitable information is contained in the "Ceramo" thermocouple Catalog No. TC-16. *Thermo Electric Co.*

1711. Fluidized Bed Units

Flyer issued by *Alexander Saunders & Co.* details the advantages of a fluidized bed unit in many heat processing operations.

1712. Crystal Growing

Process Data Sheet 660(1) will bring you information on precise temperature controls for growing metal crystals. *Leeds & Northrup.*

1713. Thermocouple Components

Catalog G100-3 illustrates line of thermocouple components — wires, insulators, protecting tubes, heads, blocks, connectors and miscellaneous components. *Minneapolis Honeywell.*

1714. Temperature Crayons

Tempil Corp. will send pamphlet discussing "Tempilstik" crayons available in temperature ratings from 100 to 2500° F.

1715. Isothermal Quench

Bulletin 700 from *Ajax Electric Co.* describes "Ajax Cataract" quench which provides uniformity, accuracy and reproducibility as well as freedom from cracks, distortion and surface defects.

1716. Thermocouple Alloys

36-p. catalog-manual contains detailed data on Specification 3G-220 thermocouple alloy as well as the complete family of Chromel-Alumel thermocouple, lead-wire, and mechanical grade alloys. *Hoskins Mfg. Co.*

1717. Heat Treating Ovens

Bulletin 157 from *Young Brothers Co.* discusses accurate, dependable heat treating ovens built for process requirements up to 1000° F.

1718. Heat Treating Equipment

The bellows effect of the sturdy but lightweight corrugated design absorbs thermal stresses as no other construction can do. Catalog No. 61 from *Stanwood Corp.*

1719. Gas Alloying

Brochure from *Lee Wilson Engineering Co.* details the advantages of the open coil process of gas alloying to produce better, more uniform high-strength steels.

1720. Straight-Line Furnaces

For critical heat treating with precise and flexible control, "SNX Series" furnaces are useful for sintering, brazing and other heat processing operations in the range 1300 to 2900° F. Pamphlet from *Pereny Equipment Co.*

1721. Induction Heaters

Brochure from *The Ohio Crankshaft Co.* reviews "Toccotron" radio-frequency induction heating equipment from 5 to 300-kw. output.

1722. Gas Carburizing

Surface Combustion Div. has released leaflet presenting data on the "Allcase" furnace for treating a variety of small parts in a carbon-controlled atmosphere, automatically adjusted.

1723. Heat Treating Furnaces

Bulletin 219 from *Johnston Mfg. Co.* presents the facts on batch-type heat treating furnaces — bottom charged, controlled atmosphere, automatic quench.

1724. Muffle Tube Furnaces

The Electric Furnace Co. has prepared a brochure which discusses fuel-fired, hump-type wire mesh belt furnaces for bright annealing of stainless steel and alloy parts.

1725. Indicating Controller

The "Sensitrol" pyrometer instrument has an accuracy of 0.5% of full scale and a sensitivity of 0.1%. Data from *Weston Instruments Div.*

1726. Sintering Furnaces

Harper Electric Furnace Corp. has released Bulletin MSF-361 illustrating line of mesh belt furnaces for sintering ferrous parts.

1727. Quench Oil Coolers

Bell & Gossett Co. has prepared combined catalog and simplified selection manual for "Hydro-Flo" self-contained quench oil coolers.

1728. Optical Pyrometers

Solve high-temperature measurement problems beyond the scope of conventional pyrometers with "Pyro-650", a fully automatic optical brightness pyrometer. Bulletin No. 614 from *Instrument Development Laboratories, Inc.*

1729. Induction Heating Equipment

"Ther-Monic" manufactures complete range of induction heating equipment (electronic, low-frequency, motor-generator) for hardening, brazing, forging, annealing, melting and sintering. *Induction Heating Corp.*

1730. Refrigeration Cabinets

Equipment from *Revco Inc.* produces temperatures to —140° F. for research and testing applications. Folder "Selecting a Low-Temperature Cabinet".

1731. Gas Burners

"Buzzer" burners need no blowers, power or other auxiliary equipment to effect combustion; simply connect it to the available gas supply. Data from *Charles A. Hones Inc.*

1732. Heat Exchangers

Bulletins 120, 124 and 132 describe the "Aero" heat exchanger for controlling the temperature of your quench bath. *Niagara Blower Co.*

1733. Induction Heating

High-frequency induction heating equipment is a practical and efficient source of heat for industrial applications such as annealing of stainless parts and many brazing operations. *Lepel High Frequency Laboratories.*

1734. Pyrometers

Pamphlet issued by *The Bristol Co.* describes complete line of thermocouples and pyrometer accessories.

1735. Furnace Tubes

The Pressed Steel Co. has released brochure setting forth the advantages of all-sheet construction for furnace tubes.

1736. Temperature Control

Dependable automatic control of temperatures (from —100 to 3000° F.) in industrial furnaces is obtained with the "Pyrotroller". Pamphlet from *Alnor Instrument Co.*

1737. Heat Treat Salts

Eliminate scaling and decarburization in heat treating without special atmospheres — through the use of "Aeroheat" salt baths. Pamphlet from *American Cyanamid Co.*

1738. Optical Pyrometer

Instantly measures temperatures of minute spots and fast moving objects; ranges: 1400 to 7500° F. Catalog No. 85 from *Pyrometer Instrument Co.*

1739. Quenching Oils

Texaco has prepared interesting booklet entitled "Fundamentals of Quenching and Hardening".

1740. Industrial Furnaces

Exclusive "Thermoshell" heating units assure rapid heating and better heat distribution in furnaces made by *Cooley Electric Mfg. Corp.* Catalog available.

1741. Temperature Indicators

The *Markal Co.* will send you literature covering the "Thermomelt" line of temperature crayons; accurate to within 1%.

1742. Program Control

When temperature uniformity is a must, reproduce your heat treating cycles with new master-slave program control. Brochure from *Leeds and Northrup.*

1743. Plugs and Jacks

"Quick-Konnect" plug assemblies provide fast, foolproof connections of thermocouples to extension wires to instruments. Specification Sheet FS 005-3 from *Minneapolis-Honeywell.*

1744. Heat Treating Costs

General Electric Co. will send you Bulletin GER-1751 telling how to prepare an economic study of your heat processing operations.

1745. Thermocouple Assemblies

Catalog G100-1 summarizes data on over 100 complete thermocouple assemblies, available in a range wide enough to cover most applications in any industry. *Minneapolis-Honeywell.*

1746. Quenching Hints

E. F. Houghton & Co. will send booklet, "Houghton on Quenching", which analyzes quenching problems and recommends optimum quenches.

1747. Semiconductor Production

"The Way to Better Semiconductor Production", a 20-p. booklet issued by *Lindberg Engineering Co.* illustrates equipment for the precise control of semiconductor production.

1748. Thermocouple Materials

10-p. catalog details the processes used to produce "Tempak" thermocouple materials and presents specifications on metal-sheathed, ceramic-insulated wire. *Temptron, Inc.*

Circle appropriate number on Reply Card, p. 48-B

MUELLER CAN MAKE MOST ANYTHING IN SINTERED METAL PRODUCTS...

Sintered metal gears, cams, special purpose filters and structural members from iron, nickel, stainless steel, brass and copper alloys are produced by Mueller for practically every segment of American industry. Whatever your product requirements are, the Mueller Sintered Metal Products Division is completely equipped to supply you with precision parts to exact specifications at substantial savings. In addition, the engineering staff, machining and finishing facilities of Mueller Brass Co. are an important plus value when you

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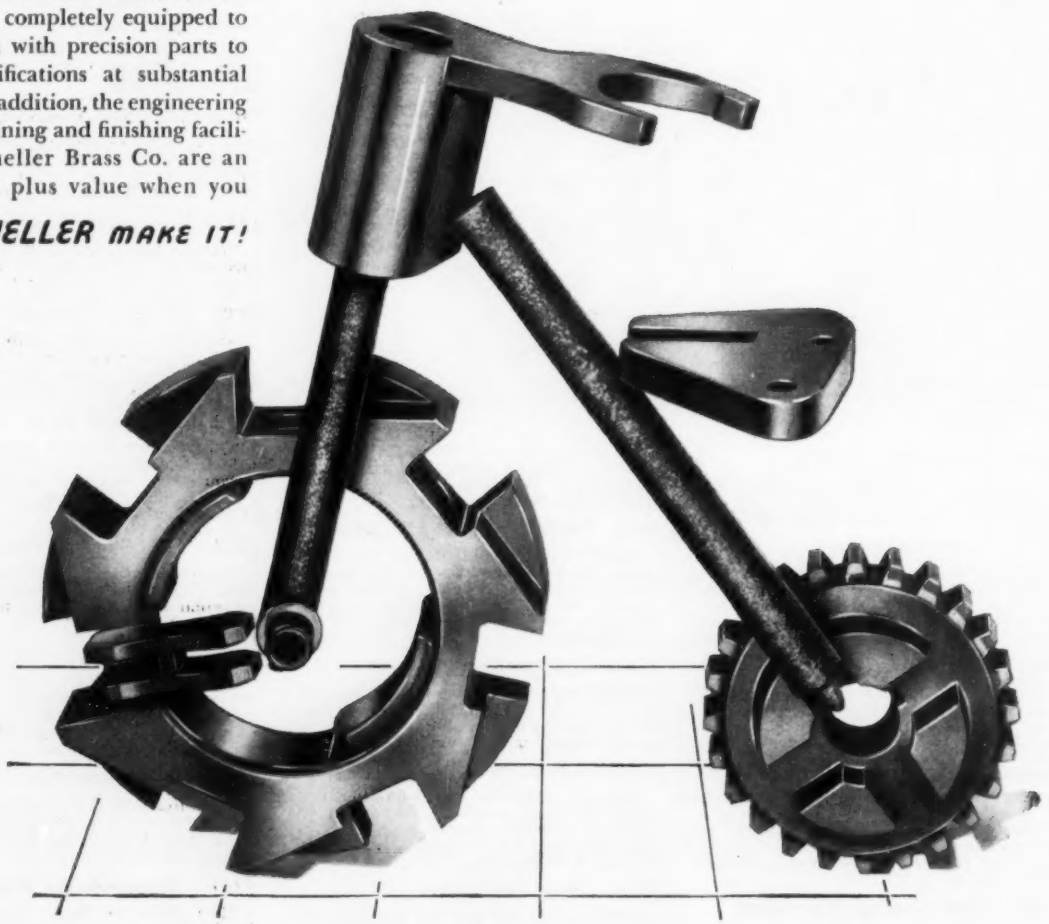


MUELLER BRASS CO.

PORT HURON 28, MICHIGAN

Circle 1866 on Page 48-E

1749. Thermal Fatigue

Electro-Alloys Div. has published "The Mechanism of Thermal Fatigue", by H. S. Avery.

1750. Fluidized Bed Heat Treating

4-p. Bulletin GED-4306 describes fluidized bed heat treating equipment for annealing, normalizing, solutioning, aging, hardening, quenching and isothermal transforming. Up to 85% reduction in heating time. *General Electric Co.*

Finishing

1752. Gold Plating

The "Autronex" acid gold plating process permits compliance with the rigid ABMA-428 specification for a hard, bright coat of gold alloy, 100 to 150 millionths in. thick covering circuit conductors. Literature from *Sel-Rex Corp.*

1753. Metal Finishing

Handbook from *R. O. Hull & Co.* gives you complete details on technical methods practiced by hundreds of leading platers to increase output and improve quality at lower cost.

1754. Electrocleaning of Copper

Bulletin F-9355 describes "Oakite 191" a compound used in electrocleaning brass and other copper alloys — with speed and without tarnish. *Oakite Products, Inc.*

1755. Deep Etching

"Metal-Etch Resist" speeds up and simplifies deep etch and weight reduction as well as parts manufacture. Pamphlet P-36 from *Eastman Kodak Co.*

1756. Mutual Chromic Acid

80-p. bulletin "Chromium Chemicals" discusses mutual chromic acid and the "Mutual" line of chromium chemicals. *Solvay Process Div.*

1757. Lapping Compound

Long, sharp "spikes" that gouge do not belong in diamond lapping compounds. Get details in bulletin from *Wheel Trueing Tool Co.*

Welding

1759. Hi-Temp Brazing Alloys

In brazing honeycombs, selection of brazing alloy is at least as important as the metals to be brazed. Brochure from *G.E.'s Metallurgical Products Dept.* tells about brazing alloys, effective to 1800° F.

1760. Micro-Wire Welding

Bulletin DM-159 describes the "Model 1259" micro-wire welder for joining sheet metal, using CO_2 or argon gas shielding. *Hobart Bros. Co.*

1761. Electron Beam Welding

To learn more about electron beam welding, send for pamphlet issued by *Sciaky Bros., Inc.* Low voltage and redesigned chamber eliminate x-ray hazards.

1762. Silver Brazing

Pamphlet No. 20 from *Handy & Harman* gives a good picture of silver brazing and its benefits, and includes details on alloys, heating methods, joint design and production techniques.

1763. Welding Mild Steel

20-p. brochure tells how to weld mild and low-alloy steels and includes specifications, operating characteristics, mechanical properties and applications. *The McKay Co.*

1764. Welding Wires

Catalog F-1486 from *Linde Co.* describes "Oxweld" electric welding wires and rods.

1765. E-B Welding

Brochure explains "Hamilton-Zeiss" electron beam welding and cutting machines used in processing many of today's most difficult materials. *Hamilton Standard Div.*

1766. Rectifier Welders

"Gold Star SRH-444" rectifier-type d-c. welders offer speed, versatility and economy never feasible with motor-generator sets. Brochure from *Miller Electric Mfg.*

1767. Plasma Spraying

Folder entitled "Plasma Bond Spraying Service" describes applications and fabrication techniques for metallic-ceramic coatings. *Thermal Dynamics Corp.*

1768. Plasma Coating

12-p. booklet illustrates the plasma coating process, and presents properties and uses of coatings. *Plasmatech Div.*

1769. Adhesive Specifications

Minnesota Mining and Mfg. Co. has published 54-p. compilation listing U.S. Government specifications for adhesives, coatings and sealers.

1770. Welding Alloy Wall Chart

Welding, brazing and soldering alloys and fluxes are rapidly selected according to the base metal to be joined. *All-State Welding Alloys Co.*

1771. Electron Beam Welder

The "Mark VI" electron beam welder makes possible what has previously been impossible in welding and brazing of refractory and reactive metals. Data from *Alloyd Electronics Corp.*

Testing

1773. Cathodic Vacuum Etching

Folder prepared by *Nuclear Materials and Equipment Corp.* describes the "Model 4 CVE" cathodic vacuum etcher for developing the microstructure of metals, ceramics, and cermets for examination by optical or electron microscope.

1774. Ultrasonic Inspection

Ultrasonics, Inc. will send brochure discussing the capabilities of modern ultrasonic inspection systems.

1775. Microhardness Tester

The *William J. Hacker Co.* has published reprint entitled "A Contribution to the Practical Application of the Microhardness Tester", by L. Willing, Vienna.

1776. "The Laboratory"

32-p. journal features new developments in instruments, apparatus, lab furniture, reagent chemicals, and methodology. *Fisher Scientific Co.*

1777. "Edgegraphing"

16-p. data sheet explains Edgegraphing, a new technique for hand analysis of complex engineering data in 10, 20, or more variables. *Statistical Engineering Institute.*

1778. Testing of Metals

Ten-page Bulletin M-2 from *Instron Engineering Corp.* covers all fields of precision metals testing.

1779. Research Metallographs

Information on important features and conveniences built into the "Model MM5" micrometallograph is available from *E. Leitz, Inc.*

Circle appropriate number on Reply Card, p. 48-B

LET MUELLER MAKE IT!

Mueller Brass Co. of Port Huron is much more diversified than the name "Brass" implies . . . a lot more. In fact, because of its many and varied facilities . . . its *men, methods* and *metals* . . . Mueller is in the unique position of being able to offer true single source service.

MUELLER HAS THE MEN . . . experienced engineers with the ability to work out, creatively, tough design problems, and improve a part or components for production by the most economical method. You get sound engineering plus 44 years of practical metalworking production experience when you "Let Mueller Make It."

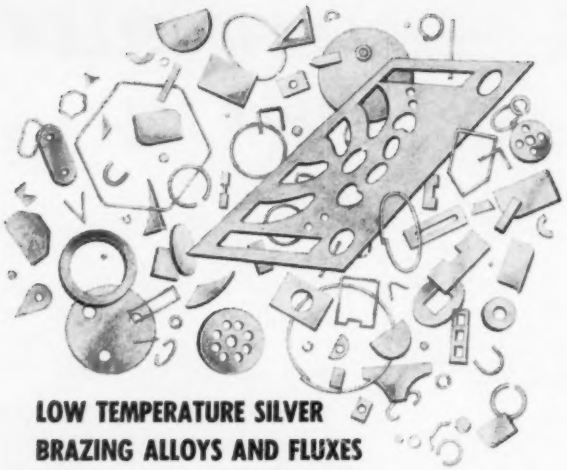
MUELLER HAS THE METHODS . . . when you "Let Mueller Make It", you are utilizing one single source that is able to produce parts any one of these ways: as forgings, impact extrusions, sintered metal parts, screw machine products, formed tube or as castings.

MUELLER HAS THE METALS . . . and the materials . . . to produce precision parts in aluminum, brass, bronze, copper, iron, and steel in hundreds of different alloys to meet each exact requirement.

In addition, Mueller Brass Co. has complete and modern facilities for performing all types of finishing and sub-assembly operations. Another plus value is nation-wide sales engineering service.

So, in the final analysis, no matter where you fit in the American industrial picture, whether you're making missiles or mowers . . . and no matter where you're located, it will pay you to LET MUELLER MAKE IT!

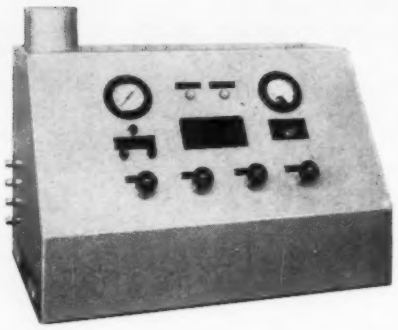
MUELLER BRASS CO.
PORT HURON 28, MICHIGAN



LOW TEMPERATURE SILVER BRAZING ALLOYS AND FLUXES

Select a brazing alloy "tailored" to your precise requirements from the complete line of Silvaloy Low Temperature silver brazing alloys and fluxes. Silvaloy bond is as strong or stronger than the metals joined...available in wire, coil, strip, plymetal or preformed shape most convenient and economical for your production procedure. • Silvaloy is used by the country's leading manufacturers to speed and simplify production, to assure highest quality work, at lowest cost. Write for literature.

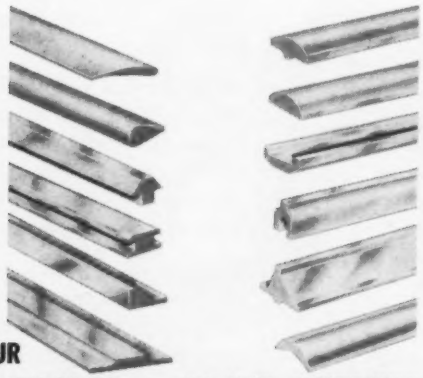
AMERICAN PLATINUM & SILVER DIVISION
231 N. J. RAILROAD AVENUE • NEWARK, N. J.



ENGELHARD HYDROGEN DIFFUSION PURIFIER

This Hydrogen Purifier removes all impurities (including oxygen, nitrogen, argon, water vapor, hydrocarbons, etc.) from hydrogen gas streams. Produces hydrogen of highest purity obtainable from dissociated ammonia, steam reformed natural gas or propane, commercial hydrogen purchased in cylinders and other hydrogen containing gas streams. *No trace of impurities detectable in purified gas.* Ultra-pure product hydrogen obtained at lowest cost. • Available in standard sizes: 100 c.c. per hour, 20 SCFH, 75 SCFH, and 150 SCFH. Larger sizes custom built to requirements. Write for literature.

INDUSTRIAL EQUIPMENT DIVISION
GAS EQUIPMENT SECTION
113 ASTOR STREET • NEWARK, N. J.



CONTOUR ROLLED STOCK TO ± .001 INCH DIMENSIONS

New Makepeace development produces contoured strip stock with cross sections formed of one or more curved surfaces to tolerances as close as ±.001"—with temper fully controlled. Finishes down to 8 micro-inches maintained . . . blending of multiple radii accomplished with minimum varation. Extremely intricate angles and combinations rolled into rod, wire, tubing and sheet. Any cold-workable material suited to process, i.e., aluminum, copper-base alloys, stainless steels, waspalloy, titanium, cobalt-nickel alloys, inconel and monel. Contoured stock parts ideal for machinery, appliances, engines and fittings.

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PINE & DUNHAM STREET • ATTLEBORO, MASS.

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* * *

Please send literature as indicated below, addressed to my attention:

☐ High Diffusion Purifier ☐ Contour Rolled Stock

☐ Silver Brazing Alloys and Fluxes

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TITLE.....

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STREET.....

CITY..... ZONE..... STATE.....

Circle 1867 on Page 48-B

1780. Electrolytic Polisher

The only instrument which permits constant observation of the etching process. Complete information may be obtained from *Ercona Corp.*

1781. Metallurgical Microscopes

Catalog No. 2-T from *Unitron Instrument Co.* discusses wide range of metallurgical microscopes for every type of metallurgical application.

1782. Electron Microscope

Literature from *RCA* tells about versatility and adaptability of the "Model EMU-3" electron microscope.

1783. Universal Testing Machine

The "Model ULH-60" universal testing machine, with a capacity of 60,000 lb., accommodates all test specimens within a single testing space; loading rate 0 to 3 in. per min. Information from *Budd.*

1784. Fatigue Testing Machine

Bulletin RF-2-61 explains "Riehle-Los" hydraulically actuated fatigue testing machine — complete with specifications, accessories and hydraulic flow charts. *Riehle Testing Machines.*

1785. Metallographic Equipment

Bausch & Lomb metallographs help industry boost output and maintain quality by providing detailed magnified images — visual or photographic — for routine work in advanced research. Catalog E-240.

1786. Hardness Testing Equipment

Two flyers prepared by *Advance Industries, Inc.* discuss a portable hardness tester, which electromagnetically attaches to material to be tested; and a horizontal hardness tester designed for accuracy, utility and convenience.

1787. Automatic Test Machine

The "TM-1 Autodynamic" elevated-temperature test machine is a fully automatic, servo-controlled universal testing machine which measures and records modulus, yield, ultimate strength, and other mechanical properties of materials. Details from *Marquardt Corp.*

1788. Sheet Metal Tester

Now a complete sheet metal testing facility is contained in one bench model machine. This is discussed in Bulletin 62 from *Tinius Olsen Testing Machine Co.*

Casting

1809. Nodular Iron

Solve your tough testing problems with "Meehanite" nodular iron. 8-p. brochure No. B-47-A from *Meehanite Metal Corp.*

1810. Industrial Mixers

Mixing Equipment Co. will send details on "Lightnin" mixer for a wide range of industrial mixing applications.

1811. Polymers for Core Oil

Booklet published by *Velsicol Chemical Corp.* tells how polymers and core oils produce cores of greater strength and uniformity and how faster baking speeds may be obtained.

1812. Gas Generator

4-p. Bulletin GED-4307A explains how "Hydralene" gas producers provide a steady source of high-purity hydrogen gas with material cost about 10% of cylinder gas. *General Electric Co.*

1813. Bulk Supply Systems

24-p. Booklet N-155 from *National Cylinder Gas Div.* outlines bulk supply systems for gaseous and liquid oxygen, nitrogen, and argon.

1821. Maintenance and Repair

16-p. booklet published by *LaSalle Steel Co.* offers helpful solutions to the problems of getting machinery repaired and back into production fast, and at minimum cost.

Parts

1829. Decimal Chart

A decimal equivalent chart designed for quick conversion of Birmingham wire gages and fractions to decimals is available from *Ohio Seamless Tube Div.*

1830. Metal-Mesh Belts

The Cambridge Wire Cloth Co. has released 130-p. reference manual which illustrates line of metal-mesh belts.

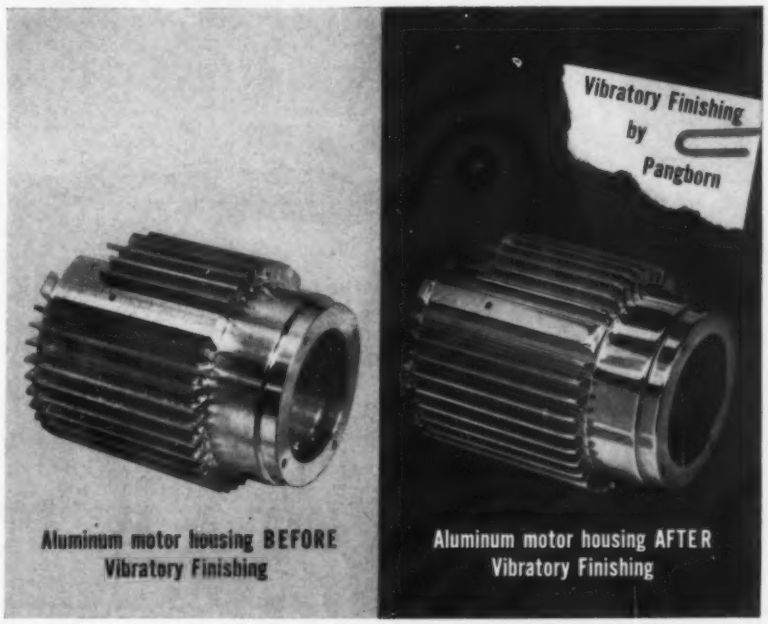
1831. Special Steels and Alloys

Booklet "Products for the Design Engineer" contains a useful stainless steel selector chart and information on high-strength steels, titanium, electrical steels, vacuum arc-melted steels and other high-performance metals. *Republic Steel Corp.*

1832. Special Stainless Shapes

G. O. Carlson Inc. has published booklet "Producing Stainless Steels . . . Exclusively," which describes facilities and products.

Circle appropriate number on Reply Card, p. 48-B


Vibratory Finishing by Pangborn
Aluminum motor housing BEFORE Vibratory Finishing
Aluminum motor housing AFTER Vibratory Finishing

Amazing, how inexpensive complex finishing can be!

In some cases, the Pangborn Vibratory Finishing Machine has reduced finishing time by over 90%. You know what this means in time and labor savings alone. Especially since this machine tackles complex finishing assignments with the same ease and speed as simple ones.

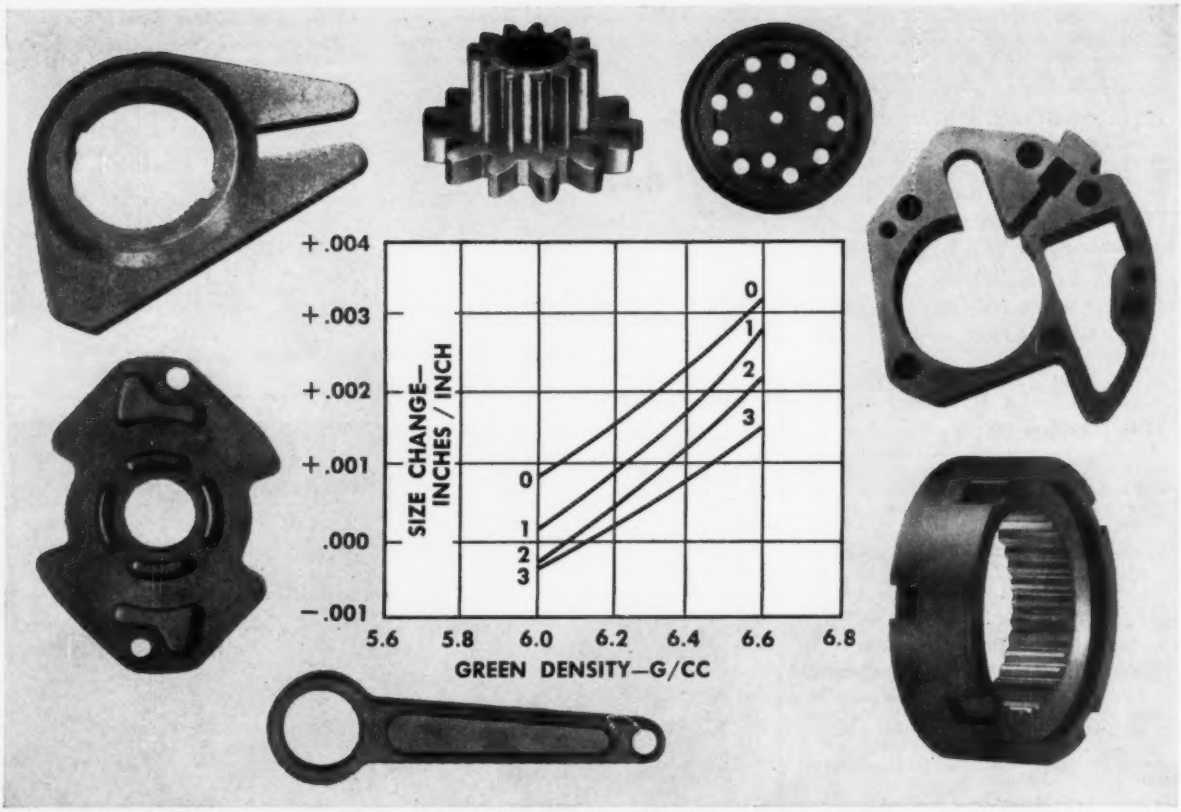
Its uses are amazing, too. It descales, deburrs, burnishes, radiuses, fine-finishes. It handles a wide variety of materials . . . metals, plastics and ceramics. And this machine tackles complex and difficult jobs impossible or impractical to do by other methods . . . and does them quickly and economically.

The exclusive air-cushioning system built into every Pangborn Vibratory Finishing Machine provides better and closer amplitude control and offers automatic adjustment for any weight load. Air-cushioned floor mounts eliminate any transmitted vibration. No special foundations are necessary. Variable speed controls available on all models. Automated and auxiliary equipment, media, compounds for every need. Send parts with exact finish specifications or finished specimen for sample processing in our laboratory to Mr. William Brandt at:

PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md., Pangborn Canada, Ltd., 47 Shaft Rd., Toronto (Rexdale), Canada—*Manufacturers of Vibratory Finishing, Blast Cleaning, Dust and Fume Control Equipment; Rotoblast® Steel Shot and Grit®.*

Pangborn
OF HAGERSTOWN

Circle 1868 on Page 48-B



Better dimensional control, with economy ...when you use A.W. Iron Powder

Little differences in the carbon additive to A.W. Iron Powder can make big savings in your plant.

By use of different types of carbon additives, in iron-copper-carbon mixes, a broad range of dimensional control can be achieved. This provides not only greater latitude in design specifications, but prolongs the service life of your dies. Together, these advantages result in closer tolerances for your molded parts at reduced production costs.

The curves shown above indicate the range of dimensional change obtainable with various types of carbon. *The cost of all these grades is almost identical.*

The Alan Wood 50-ton-a-day direct reduction plant, backed by years of metallurgical research, offers you the most advanced technology in Iron Powder. Make Alan Wood your Iron Powder headquarters for dependable uniformity and delivery, as well as technical advisory service.

ALAN WOOD STEEL COMPANY
CONSHOHOCKEN, PA.

FOR MORE INFORMATION

IRON POWDER DIVISION
ALAN WOOD STEEL COMPANY
Conshohocken, Pa.

Please send me A.W. Technical Data Bulletin #3, which gives additional details on copper-carbon additives.

NAME AND TITLE _____
COMPANY _____
ADDRESS _____
CITY _____ ZONE _____ STATE _____

AMERICAN STEELMASTERS FOR 135 YEARS

Circle 1869 on Page 48-B

Photo courtesy of J. W. Rex Corp.

To hit the exact qualities you want . . . you need a choice of quenching oils

You can *get by* with just one quenching oil. But you can't always get the *best results* . . . not when you measure quality to a fine degree. Very often, you need a choice.

Sun makes quenching oils to reduce cooler-maintenance costs... oils with high antidecomposition qualities . . . oils for fast-quenching operations . . . oils for marquenching . . . and other "specials."

See your Sun representative for help in evaluating your quenching needs. He'll show you how to save money while maintaining quality . . . the best economy of all.

SUN OIL COMPANY, Philadelphia 3, Pa. Department MP-11. In Canada: Sun Oil Company Limited, Toronto and Montreal.

SUNOCO

MAKERS OF FAMOUS CUSTOM-BLENDED BLUE SUNOCO GASOLINES

Circle 1870 on Page 48-B

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

How Alloy Steels Respond to Induction Hardening

In the induction-hardening process, steel is first heated above the transformation range by means of electrical induction, then quenched as required. Special equipment is needed, and heat is developed as follows:

High-frequency alternating current passes through a coil or inductor, with the result that a magnetic field is created in the coil. When the piece to be treated is placed in this field, it is heated rapidly by induced energy. With the various types of induction-heating equipment, the process is capable of surface- or case-hardening to various controlled depths; however, through-hardening can be obtained with certain alloy steels. Ferrous metals that respond well to induction hardening include numerous grades of both alloy and carbon steels, as well as hardenable stainless steel and plain or alloyed cast iron.

As a rule, when alloy steels which contain non-carbide-forming elements, such as nickel, are heated by induction, the usual hardening temperatures can be used. But with alloy steels that do contain carbide-forming elements such as chromium, molybdenum, and vanadium, the hardening temperature must be increased if the normal effect of the alloying elements is desired.

Hardness obtained by the induction process is a function of the carbon content and prior structure, just as it is when conventional heating methods are used. Nevertheless, higher surface-hardness values for a given carbon content have often been noted in parts subjected to surface induction-hardening. The extra hardness may be as much as five Rockwell C points for steels of 0.30 pct carbon.

As pointed out previously, the induction method requires special equipment. However, it possesses several marked advantages, including speed of heating and cleanliness of operation. Pieces heated by induction are usually subject to a minimum of scaling and distortion. Moreover, induction-hardening equipment is very compact and therefore conserves floor space.

If you would care to know more about the induction hardening of alloy steels, please communicate with our technical staff. Bethlehem metallurgists have made a thorough study of the subject, including the many details of quenching and tempering. Call them if they can help you in any way. And remember, too, that Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

Steel

for Strength . . . Economy . . . Versatility

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 1871 on Page 48-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

November, 1961 Issue
METAL PROGRESS

BUSINESS REPLY CARD
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FIRST CLASS
PERMIT NO. 146
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MICH.

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METAL PROGRESS
215 WAYNE STREET
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METAL PROGRESS

BUSINESS REPLY CARD
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FIRST CLASS
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Metal Progress November, 1961 Issue
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Cards not valid without company name, or if used after January 31, 1962.

Complete Reader Service Information With These Convenient Prepaid Cards

Catalogs and bulletins, new products and services and most advertisements in Metal Progress are numbered. To receive more information, circle the appropriate numbers on one of these postage paid cards. Editorial reprints will be sent free as long as they last.

Catalogs and Bulletins are available from a *scrutinized* and up-to-date list of manufacturers' literature, conveniently indexed under the 11 major Engineering Areas.

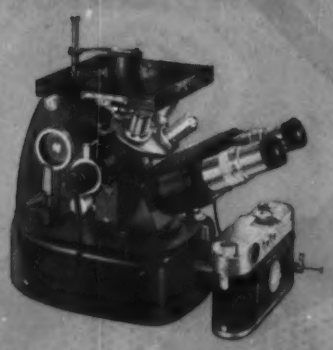
More Facts on Advertised Products. Because some advertisements cannot be numbered, please write the names of those advertisers in the blanks provided.

New Products and Services are numbered. Circle the postcard for more information.

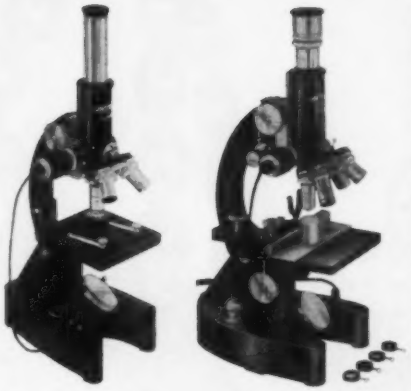
Reprints of Articles are yours for the asking as long as they last. No need to clip your Metal Progress issue for reference filing; send for reprints.

Please Include Your Name and Address!

If METALLURGY is your field, UNITRON is your microscope

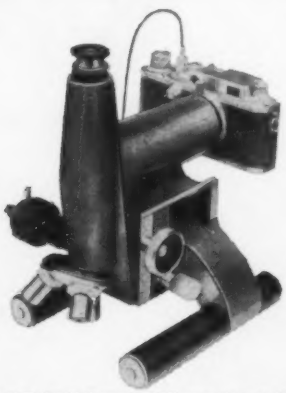


Binocular inverted Model BMEC with camera mechanism.....$615.
Monocular inverted Model MEC.....$399.
(Polaroid Land Camera attachment available)



Model MMA.....$149. Model MMU.....$287.

Binocular Metallograph BU-11.....$1379.
Monocular Metallograph U-11.....$1195.
Polaroid Land Camera attachment.....$115.

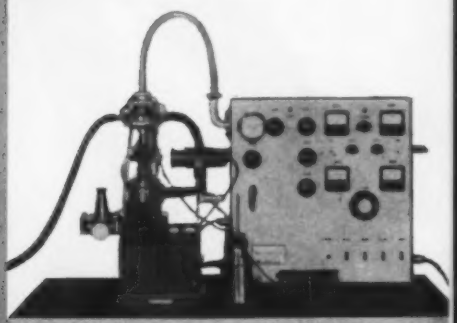


Model DMR Depth-Measuring Rollscope for examination of large or cylindrical surfaces.....$445.

Projection Screen..$95.

Toolmakers and Metallurgical Microscope Model TIS for 3-dimensional measuring.....$1090.
(other models available)

UNITRON'S Complete Laboratory Installation for High-Temperature Metallography with Metallograph and HVC-3 Control and Power Station.



Stereoscopic Model MSL.....$110.

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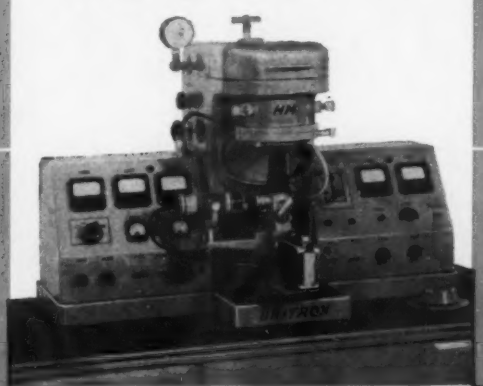

HHS-3 Vacuum Heating Stage for 1500° C.....$625.

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Circle 1835 on Page 48-B

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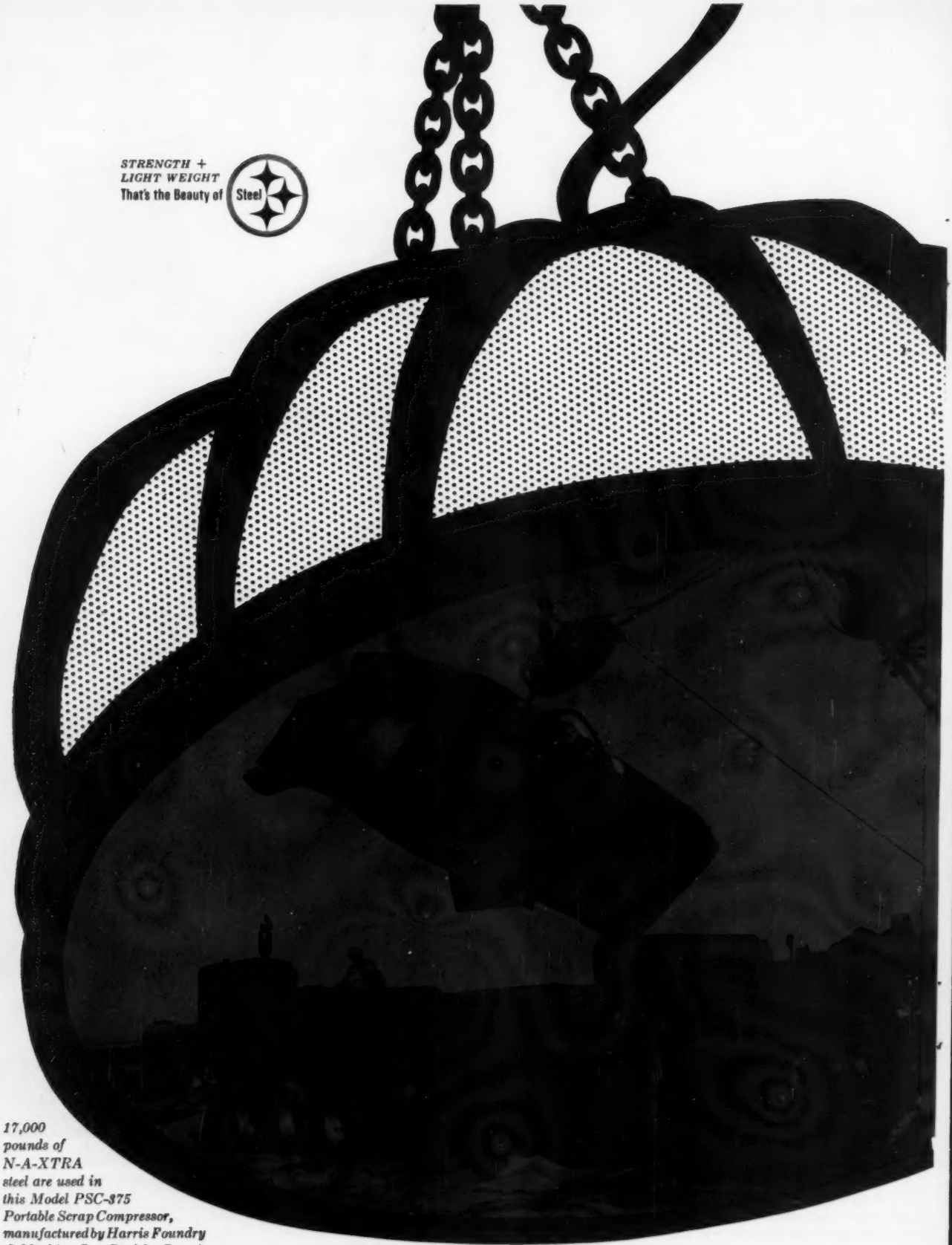
LIGHT WEIGHT
That's the Beauty of Steel



17,000 pounds of N-A-XTRA steel are used in this Model PSC-875 Portable Scrap Compressor, manufactured by Harris Foundry & Machine Co., Cordele, Georgia

STRENGTH + LIGHT WEIGHT OF

N-A-XTRA

HIGH-STRENGTH STEEL SOLVES PORTABLE SCRAP COMPRESSOR PROBLEM

This unique portable scrap compressor can squeeze an entire auto body into a 21″ x 36″ x 24″ bale of 20% dense steel scrap, using a ram pressure of 375 tons. Designed to be hauled from job to job by a conventional truck-tractor, it goes to work in outlying wrecking yards, compressing bulky scrap into marketable bales that can be shipped economically.

Because it must be moved over the highway and meet established load limits, a pressing problem in designing the PSC-375 was weight. Mild carbon steel with the required strength would weigh too much. N-A-XTRA high-strength steel solved the problem. It fully met all strength and fabrication requirements, yet kept total unit weight within acceptable limits for portability.

Portability may not be the controlling factor in your product—but the same steel that solved this problem is the one to remember when only the strongest steel will do. Pound for pound, N-A-XTRA steels are nearly three times stronger than mild carbon steel. Rugged conditions, heavy loads and weight-saving construction—in such applications, for example, as heavy machinery and pressure vessels—are challenges that N-A-XTRA is designed to meet.

With excellent weldability, formability, and toughness even at subnormal temperatures, N-A-XTRA low carbon, extra strength alloy steels give superior results with conventional fabricating methods, including cold forming, gas cutting, shearing and machining. N-A-XTRA high-strength steels are available in four levels of minimum yield strength, from 80,000 to 110,000 psi, and in sizes ranging from ⅛″ to 1″ thick, up to 72″ wide and up to 35′ long. For further information, write Product Development, Dept. MP-12, Great Lakes Steel Corp., Detroit 29, Michigan.

DESIGN NOTE: Model PSC-375, Portable Scrap Compressor, uses N-A-XTRA 100 (minimum yield strength, 100,000 psi) in engine and tank mounts, bed and side ribbing, arm housings and end housing. Sizes—¼″, 5/16″, ½″, ¾″ and 1″ thick. Fabrication followed standard gas cutting and welding procedures.

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GREAT LAKES STEEL

Detroit 29, Michigan

N-A-XTRA STEELS ARE AVAILABLE AT THESE STEEL SERVICE CENTERS

Benedict-Miller, Inc. Lyndhurst, New Jersey	Joseph Demsey Co. Cleveland, Ohio	Ducommun Metals & Supply Co. Los Angeles, California
Interstate Steel Co. Des Plaines, Illinois	Lockhart Iron & Steel Co. Pittsburgh, Pennsylvania	Marsh Steel & Aluminum Co. Kansas City, Missouri
O'Neal Steel, Inc. Birmingham, Alabama	Salt Lake Hardware Co. Salt Lake City, Utah	A. C. Leslie & Company, Ltd. Montreal, Canada

Great Lakes Steel is a Division of **NATIONAL STEEL CORPORATION**

Circle 1836 on Page 48-B

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NEW BUDD ULH-60
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In one machine, Budd combines electronic measuring and a single testing space for tension and compression testing. Net result: The utmost in precision, convenience and testing speed. The ULH-60, with a capacity of 60,000 lb., accommodates all test specimens within a single testing space . . . and affords loading at controlled rates from 0 to 3 inches per minute.

The weighing and load indicating system of the ULH-60 includes three bonded strain gage load cells and a 24-inch servo-operated illuminated dial. Five standard ranges, with individual zero adjustments, are provided. Ranges can be changed while testing. Two-unit construction lets you position the press section and the control console to suit your needs, or to combine them into a single unit that fits into less than ten square feet of floor space. No foundations or supports are required.

Specifications and details on all the features of the new ULH-60 are yours on request. Or we'll be glad to help you evaluate your needs and show you how Budd's broad line of high-performance universal and specialized machines can make your testing dollar go further.

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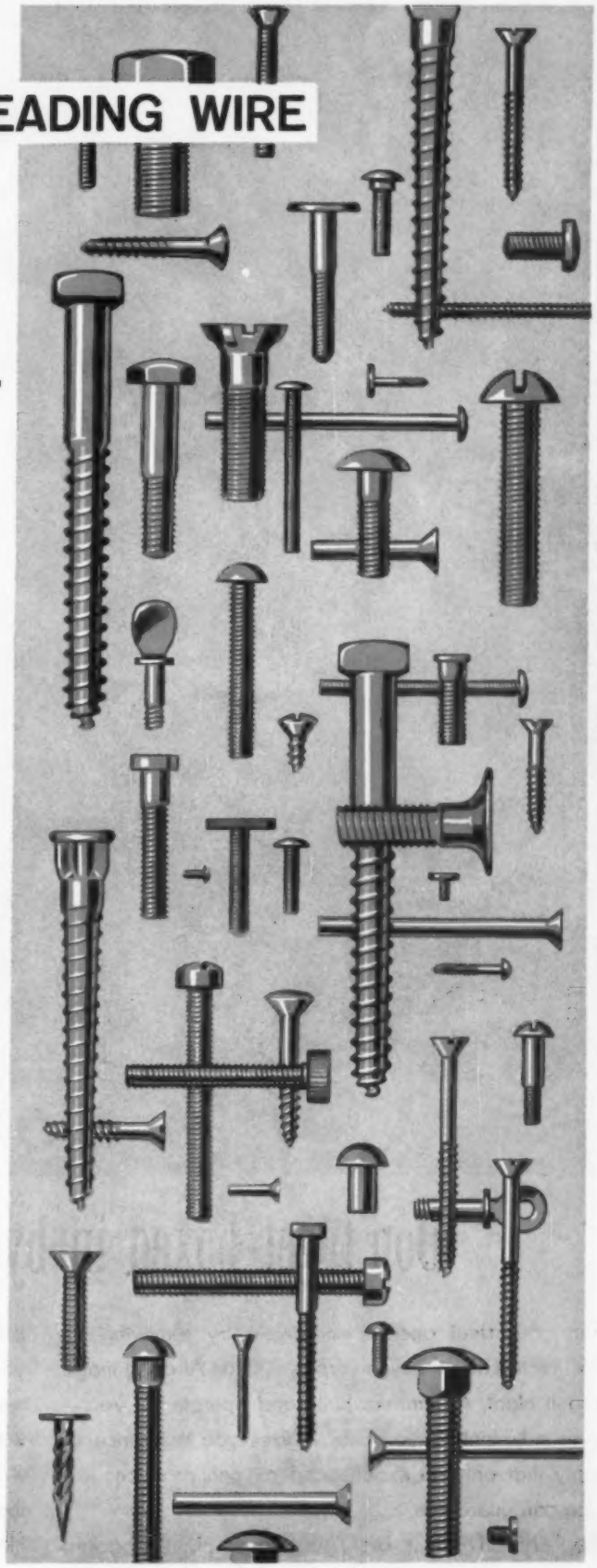
Circle 1837 on Page 48-B

ANACONDA COLD-HEADING WIRE

take a new look at the way you're making these parts...



Cold-heading and upsetting operations require specific qualities in wire to obtain the optimum in quality and the most favorable unit cost.

Anaconda Cold-Heading Wire has those qualities . . . a greater range of alloys . . . a wider range of finer characteristics to satisfy almost any requirement for a cold-headed part. These include corrosion resistance, toughness, tensile and fatigue strengths, electrical conductivity, and good color matching with other metals.

And to further improve the qualities of Anaconda Cold-Heading Wire, new fabricating methods have been developed to produce wire with a superfine-grain structure and greatly improved physical and mechanical properties. Today these new manufacturing methods can be applied to both brass and phosphor bronze wire.

Certainly it will pay you to take a new look at the way you are making these parts. Among the many alloys available in cold-heading wire form, Anaconda alone has Formbrite®, Duraflex®, and Everdur®.

Publication B-33 gives complete details. Write for your copy—or call on our Metallurgical Department to help you with your problems. Anaconda has specialists in this field to help you at any time. See your Anaconda representative, or write: Anaconda American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

61-1149

COPPER AND COPPER ALLOY COLD-HEADING WIRE

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AMERICAN BRASS COMPANY

Circle 1838 on Page 48-B

Don't get boxed in by oxygen supply problems...

Keep your steel operations flexible by removing all uncertainties about oxygen supply with an Airco tonnage oxygen plant. A plant we build and operate for you — on or adjacent to your site — gives you assurance of supply that only an experienced oxygen producer like Airco can guarantee.

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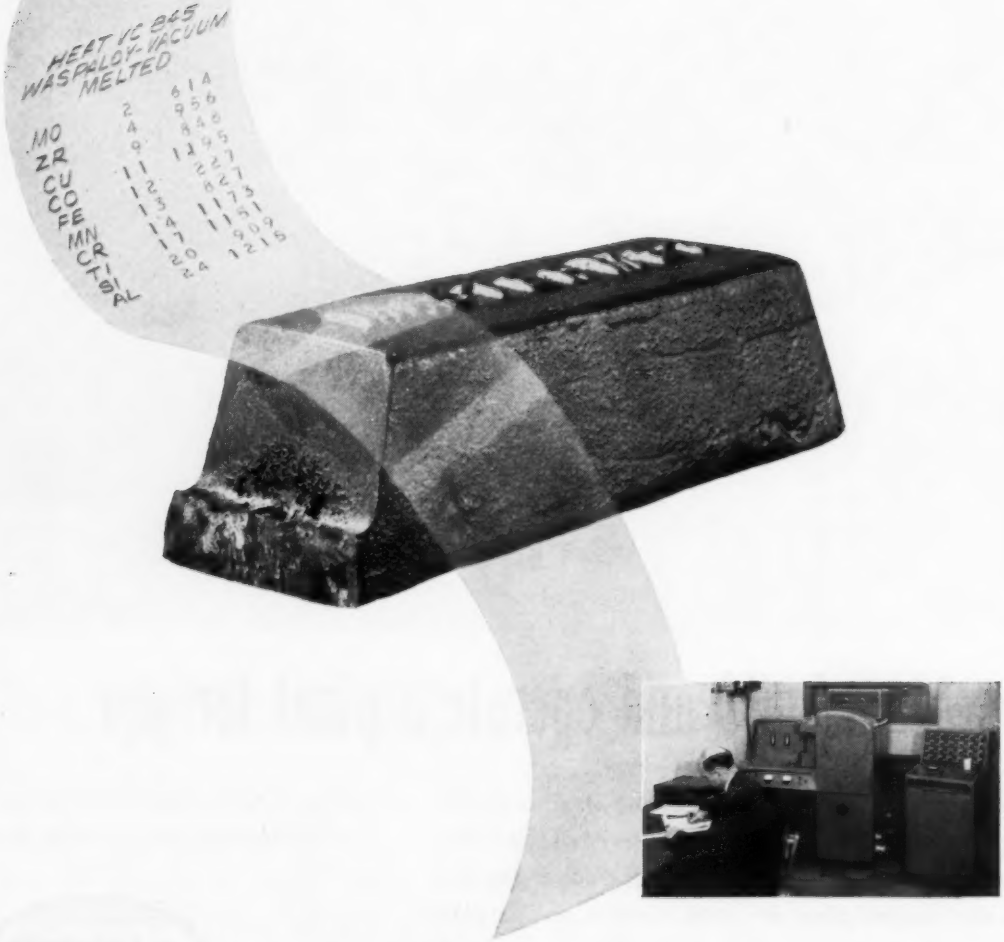
Circle 1839 on Page 48-8

NEW 15-MINUTE X-RAY OF AN ALLOY MEANS STILL HIGHER QUALITY...

STILL FASTER SERVICE FROM C-M. HERE'S THE RESULT OF A GREAT NEW ADVANCE IN QUALITY CONTROL — A COMPLETE ALLOY ANALYSIS ON PRINTED TAPE OBTAINED WITH THE UNIQUE NEW X-RAY SPECTROGRAPHIC PROCESS. THIS NEW METHOD BENEFITS YOU TWO IMPORTANT WAYS: FIRST, IT MAKES ALLOY ANALYSIS MORE ACCURATE THAN EVER BEFORE . . . WHICH MEANS ADDED CERTAINTY THAT YOUR ALLOYS ADHERE RIGIDLY TO QUALITY SPECIFICATIONS. ALSO, THIS NEW X-RAY PROCESS MAKES THE COMPLETE ANALYSIS IN JUST 15 MINUTES INSTEAD OF 3 DAYS. TOTAL RESULT: STILL HIGHER QUALITY, BETTER SERVICE, FASTER DELIVERY. A POST CARD BRINGS FULL INFORMATION.



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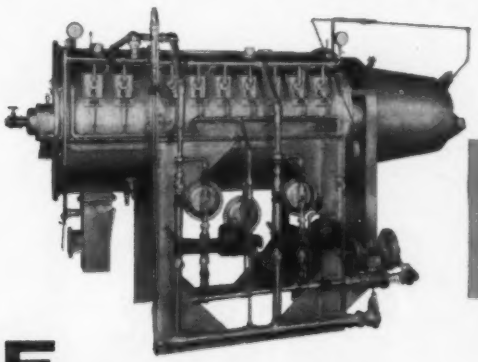
AGF

AMERICAN GAS FURNACE CO. 83 YEARS OF PIONEERING 1878 1961 ELIZABETH, N. J.

ROTARY RETORT AND RECIPROCATING HEARTH

for all small parts heat treating



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Model L36-MRB

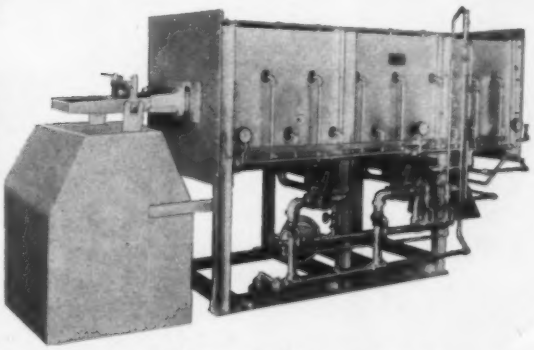
Medium size rotary furnace for the most economical heat treating of parts that can be subjected to a gentle tumbling (approximately ¼ r.p.m.).

Tumbling insures uniform heating and atmosphere contact.

AGF

Model 231

Medium size Shaker Hearth Furnace for the widest range of work, even light and delicate stampings. Momentum imparted to each work piece conveys it individually through the heat with no distortion or warpage.



Capacities to 800 lbs. per hour. Processing pieces from .010" to 1" thickness and up to 10" in length. Automatic continuous feeding reduces direct labor costs drastically! Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts, etc., are accomplished equally well WITHOUT ANY MODIFICATION OF THE FURNACE.

The muffles and retorts are, in reality, radiant tubes WITHIN which the work and atmosphere gas is contained. Zoned combustion systems uniformly heat these muffle tubes from the outside to the desired temperature in each work zone. Control is precise, results uniform.

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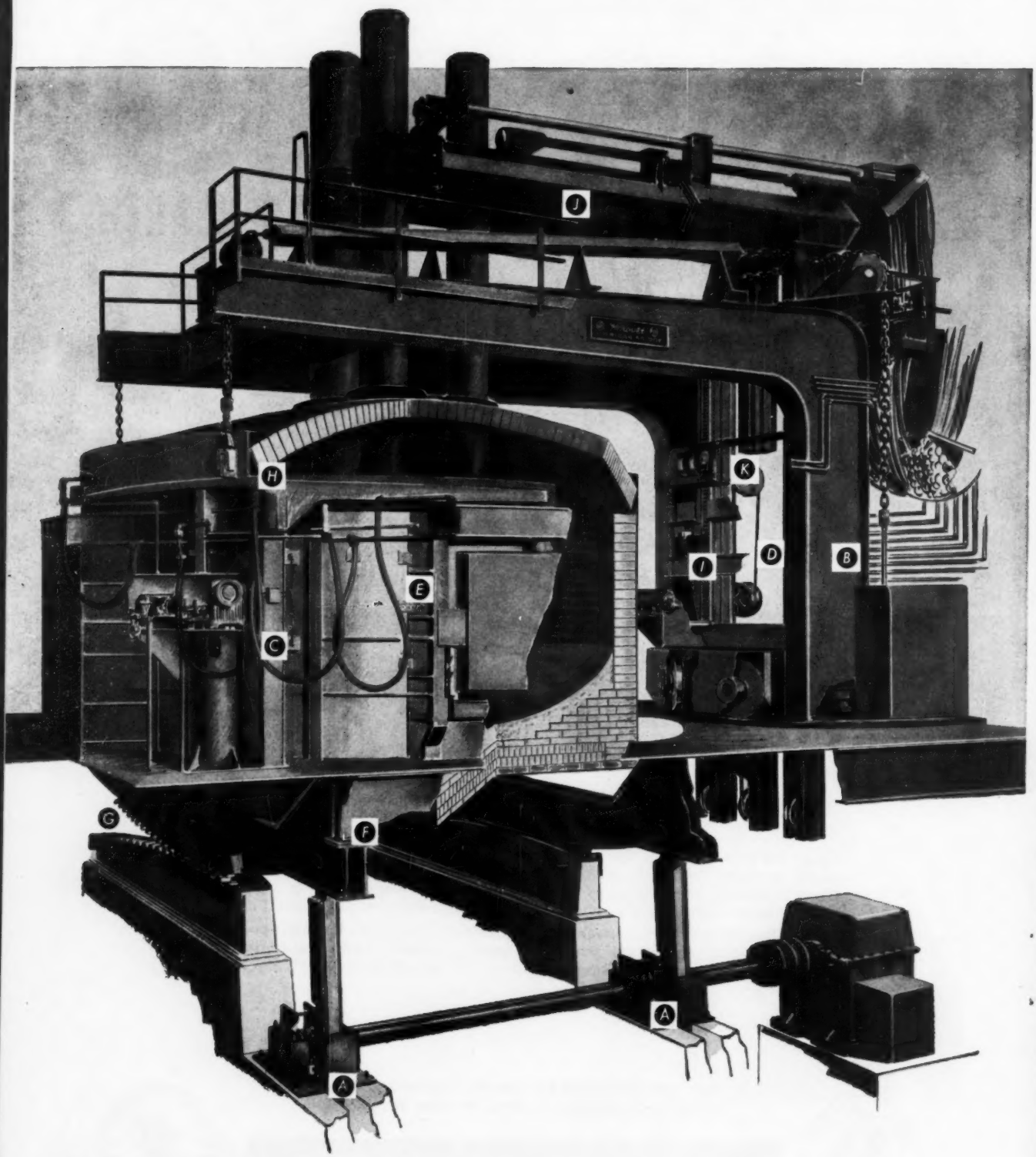
Circle 1841 on Page 48-B

More Steel...Better Steel...Faster



This mark tells you a product is made of modern, dependable Steel.

with a Heroult Electric Furnace

You can increase your steelmaking efficiency and get better steel in the bargain with a Heroult Electric Arc Furnace. Here's why: Heroult Furnaces heat fast — make more melts per day. Heroult Furnaces lower costs through high yields per heat and small scrap losses in charging. And, Heroult Furnaces improve steel quality by reducing sulfur and phosphorous content.

If you're looking for performance, efficiency, economy and low-cost maintenance, consider these features:

1. Heroult Furnaces are 100% mechanically operated. Including **(A)** heavy rack-and-pinion-type tilting mechanism, **(B)** motor-driven, rotating, jib-type roof swing, **(C)** winch-operated, water-cooled, jib-type door-lift mechanism, and **(D)** high-speed, electro-mechanical electrode-positioning mechanism.

2. Cage-type shell construction with shell plates loosely attached **(E)** to heavy supporting structure. This construction minimizes shell warping and allows easy replacement of damaged shell plates.

3. Operating mechanism independently supported. The tilting platform on which all operating mechanisms are supported is attached directly to the rockers independent of the shell structure **(F)**. Thus, operating mechanisms are unaffected by shell distortion.

4. Water-cooled, Skew Back Roof ring. This feature **(H)** eliminates the need for special skew-shaped roof refractories.

5. Electrode Mast Safety Device. This spring-loaded, rack-and-pawl-type device **(I)** provides positive protection against damage resulting from electrode winch cable breakage.

6. Square-section, Water-Cooled Electrode Mast Arms. This design **(J)** guarantees a rigid connection between mast and mast arm, thus helping to maintain proper electrode position.

7. Remote-Controlled Electrode Clamps. This device, of the spring-clamp, air-release type, is located inside of the rear section of the water-cooled mast arm where heat cannot affect it.

8. Square-Sectioned Electrode Mast. This design feature **(K)** developed by American Bridge, assures proper guiding and electrode positioning.

9. Rockers. The heavy fabricated steel curved top and bottom rockers **(G)** minimize forward travel during tilting. These rockers are designed so that the furnace will tend to return to horizontal position from any degree of tilt.

American Bridge constructs Heroult Furnaces for all types of arc melting, in charge capacities from 6,000 lbs. to 400,000 lbs. with shell sizes ranging from seven feet up. They are equipped with roof-removing mechanism for fast top charging. They can be furnished with a non-magnetic shell bottom section to accommodate induction-stirring equipment. Gantry-type top-charge furnaces, door-charge furnaces and special furnaces for duplexing and non-ferrous melting are also available. Your crew can easily maintain a Heroult Furnace. Check American Bridge's complete design, construction and installation service.

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American Bridge Division of United States Steel

USS

Circle 1842 on Page 48-S

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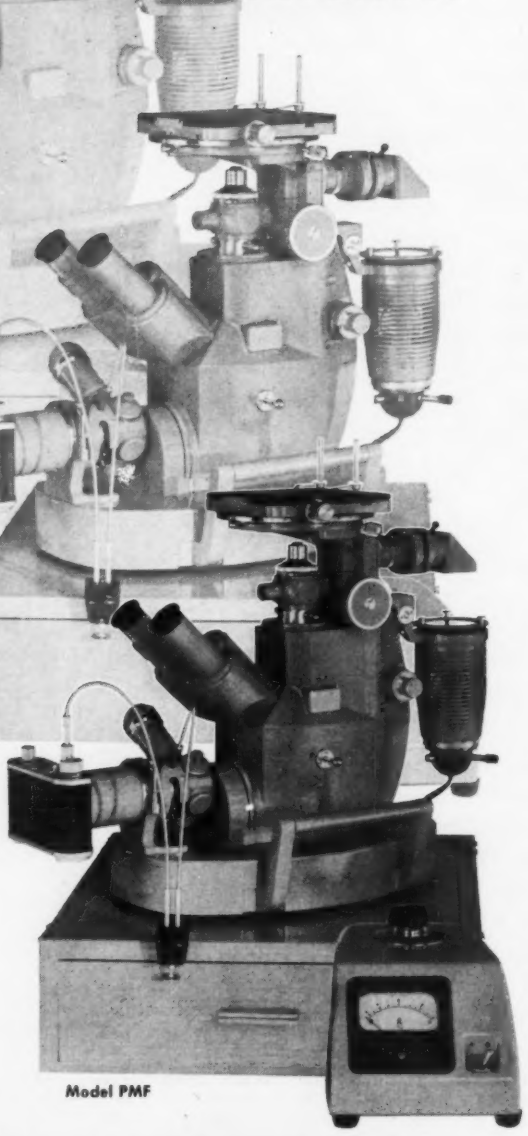
Elgeet

OF ROCHESTER . . .

Model ME



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For all your Metallurgical Microscope needs

Now, there is a quality Elgeet-OLYMPUS inverted metallurgical microscope to do every job . . . from production line inspection to complex research projects. Elgeet . . . a new standard of quality, the most remarkable value on the market today.

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Inverted metallurgical and biological microscope complete with all optical equipment. **$556.00**

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Metallurgical research microscope of the inverted "Le Chatelier" type, providing bright field, phase contrast, and polarized light illumination . . . all in one instrument. Complete with all optical equipment, built-in camera, and swivel base mount. **$2,465.00**

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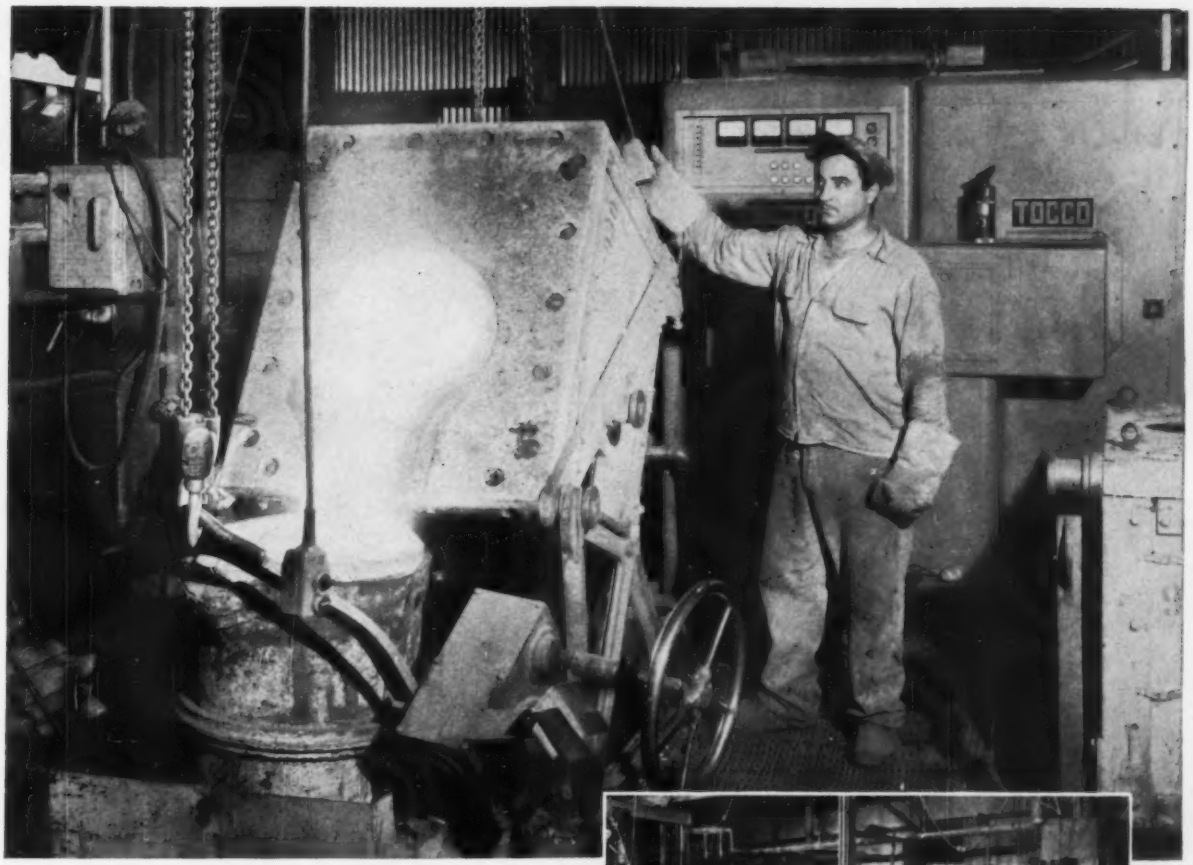
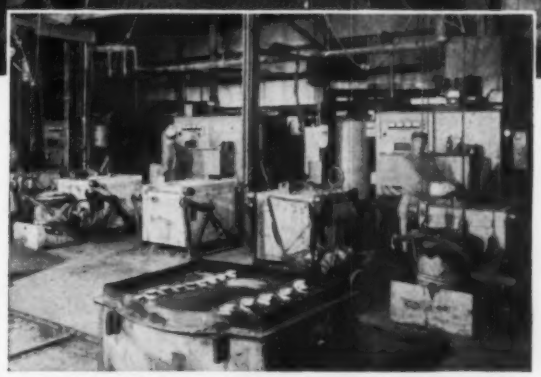
"Quality is our watchword . . . Precision Engineering our constant goal"



Precision Castings "Delivered" Overnight... in 50,000 lb. Batches



Six 600 pound TOCCO melting furnaces are powered by 700 KW of 3000 c.p.s. power at Commercial Shearing and Stamping Company, Youngstown, Ohio.

Steel casting backlogs at Commercial Shearing and Stamping Company used to lag from 8 to 10 weeks behind production schedules. By installing six 600 pound TOCCO melting furnaces, melting capacity was upped to 50,000 pounds a day—with just three operators.

Among advantages of TOCCO Induction melting are: (1) fast heating cycles—just 48 minutes for a 600 pound charge; (2) accurate control—TOCCO's completely automatic heating assures uniformity of castings; (3) cool, clean working conditions compared to conventional foundry heating methods.

If you're interested in maximum quality control, lower operating cost and rapid melting, it will pay you to learn more about TOCCO Induction melting.

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Circle 1844 on Page 48-B

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To 7-1/2" OD x .375" wall

OHIO *Square Tubing*
To 6" x 6" x .259" wall

OHIO *Rectangular Tubing*
To 7-1/2" major diameter x .259" wall
Typical 4" x 6" x .259" wall section illustrated

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OHIO QUALITY WELDED STEEL TUBING

in larger sizes...heavier wall thicknesses

OHIO SEAMLESS TUBE

Division of Copperweld Steel Company • **SHELBY, OHIO**

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

New sizes and heavier wall thicknesses of Ohio Quality Welded Steel Tubing (up to 7½" OD) now parallel the sizes of famous Ohio Seamless Steel Tubing. That means — now more than ever — there's a type and size of Ohio tube to fit your special requirements exactly. And since we make both types, we're in a position to recommend the best type for your own particular needs. Ohio Tubing — either welded or seamless — is just "made to order" for your product.

Circle 1845 on Page 48-B

Cut along line and send air mail to save time.

RUSH me, without obligation, latest information on new larger sizes and heavier wall thicknesses of Ohio Welded Steel Tubing.

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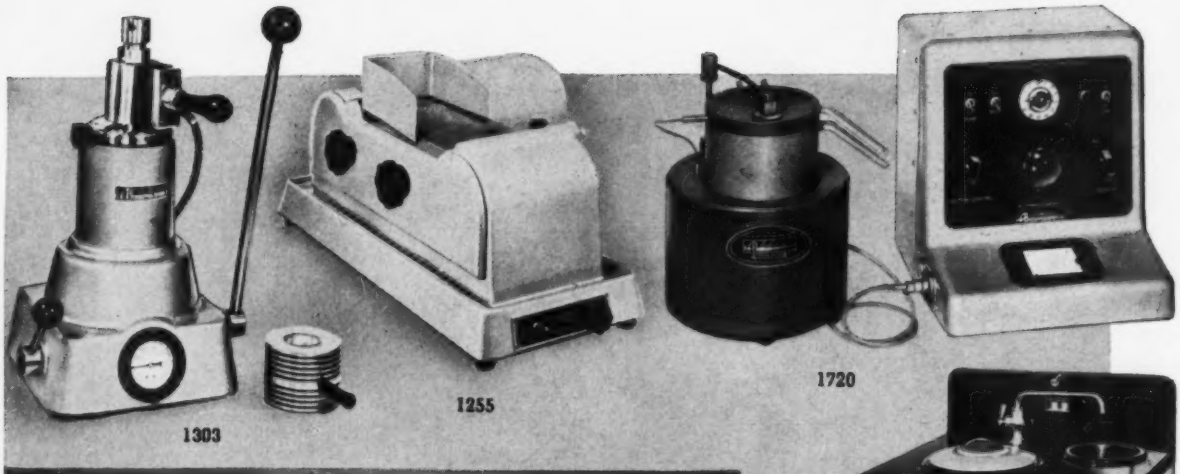

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for mounting metallurgical samples is of especially strong construction and provides unusual ease in operation. 1" and 1¼" molds are available. It accepts bakelite powder, bakelite premolds or transoptic powder.

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offers the advantages of wet grinding on silicon carbide belts. Features include fast, accurate grinding, external coolant and centering controls, easy belt change, and access for large samples with good splash protection.

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is designed for trouble free service, ease of operation and versatility in the electropolishing of metallurgical samples.

No. 1851-1 AB Polimet Polishing Apparatus

has an 8" diameter wheel with infinitely variable speed between 100 and 1200 RPM which is electrically controlled by turning a small knob. It is available also in 2 and 3 unit tables and for custom mounting.

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provides the most rapid and convenient way of fine grinding metallurgical samples by hand. Four grades of adhesive backed abrasive papers are arranged side by side with coolant flowing over them for fast clean cutting.

No. 1000 AB CUT-OFF MACHINE

is a heavy duty unit for abrasive cutting of metallurgical laboratory samples. It has a 5 HP motor, 12" abrasive wheel, built-in cooling system using jets or underwater cutting and a machine tool type positioning slide.

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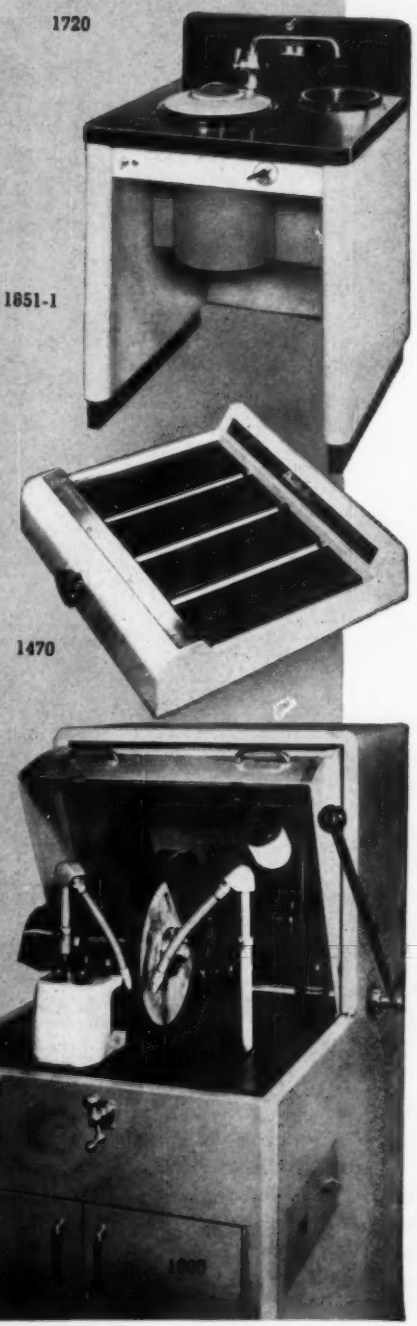

Circle 1846 on Page 48-B

METAL PROGRESS
THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING
Vol. 80, No. 5 November 1961

Critical Points

By the EDITORS

Who Will Be the Materials Engineer?

THE GROWING IMPORTANCE of engineering materials in modern technology is evident from the increased funds for research and education which are being directed into this field by government and industry. It is the lack of adequate materials which holds up the nation's progress in space, atomic energy and military hardware. To help correct this, our government has spent about $15 million in the last 18 months to set up centers at eight universities* where the fundamental aspects of materials will be studied. Although this effort will be related to space and other exotic requirements, many of the new materials uncovered will find ready use in better, more economical products for industry and home.

Commenting on the new emphasis on materials research at M.I.T., President Julius A. Stratton states that this effort "reflects the critical need for new materials in new technologies and a better understanding of the fundamental processes underlying their performance. The concept of materials today embraces familiar materials, such as wood and steel, but modern research extends its probings to crystals, molecules and atoms, seeking an understanding of how such materials succeed, fail or can be improved." Dr. Morris Cohen, A.S.M. trustee and professor of metallurgy at M.I.T., has an active part in the direction of that institution's programs in materials science.

Further indications that the fundamental study of crystals will play an important role in the future progress in materials research was evidenced at an International Conference on Nonmetallic Crystals sponsored recently by Northwestern University's New Materials Research Center, which is headed by Dr. Morris E. Fine, formerly chairman of the department of metallurgy. In reflecting on this program, Dr. Fine had this to say: "Science is learning how the structure of a material is related to its properties, such as strength, ability to conduct electricity, and the like. As the scientists better understand how structure influences properties, then engineers hopefully will be able to better tailor-make the material needed for a given application."

In commenting on the new program in materials science for which the University of Pennsylvania received $4.4 million from the Department of Defense, Dr. Gaylord P. Harnwell, president, states, ". . . there is no question but that new types of problems are confronting those who are concerned with research and development in the science of materials and those who bear a responsibility for the education of the necessary scientists and engineers." Dr. John N. Hobstetter, professor of metallurgical engineering, is director of the Materials Center at this university.

It is significant that many of the new programs in materials are being directed by scientists and engineers who have metallurgical backgrounds. This should encourage all metallurgists and metals engineers to understand the nature of the coming highly technical age and what it means by way of enlarged horizons for their profession. There is an important role for the metallurgist in the development of the science of materials because he already appreciates the significant relationship between structure and properties, so important to an understanding of the fundamental problems in materials engineering. Today's challenge in materials offers the metallurgist the opportunity to expand his interests and to broaden the scope of his activities. He can provide the leadership needed for the Materials Age, but bold thinking and a continuous interest in self-education in new areas are required. Then, as has been suggested by General Electric's John H. Holloman, who has served A.S.M. as a trustee: "Metallurgical engineering will become materials engineering. Out of metallurgy, by physics, comes materials science."

*Included are Northwestern, Cornell, Pennsylvania, Brown, Harvard, Stanford, Chicago and Massachusetts Institute of Technology.

Modern
Heat
Treatment

Induction Hardening Helps in Manufacturing These Actuators

A Superior Microstructure for Optimum Induction Hardening

*By RICHARD J. GOULD**

In the development of the hardened and tempered microstructure of steel, as commonly used in induction hardening, there exists a critical carbide particle size. A slight deviation from this critical size will result in either optimum or inferior case hardnesses. Also, prolonged tempering times adversely affect the response of the microstructure to induction hardening. (J2g, M27; AY)

INDUCTION HARDENING IS BECOMING increasingly popular as an economical and effective method of selectively case hardening steel parts. In the Actuator Operation at Saginaw Steering Gear Div., General Motors Corp., induction hardening is being used almost exclusively in the production of ball bearing screws and splines. However, to produce a case of high quality consistently on these critical components, particularly where special case hardness and case patterns are required, problems unique to the process had to be solved. One of the most important of these problems was the need for an improved microstructure which would respond more readily to the short-time cycles of induction hardening, since, it appeared, adjustments of coil design and power settings had failed to produce the desired results.

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Make Full Use of Available Carbon

With conventional carburizing, in which the carbon content of the steel is increased to concentrations between 0.85 and 1.00%, there is

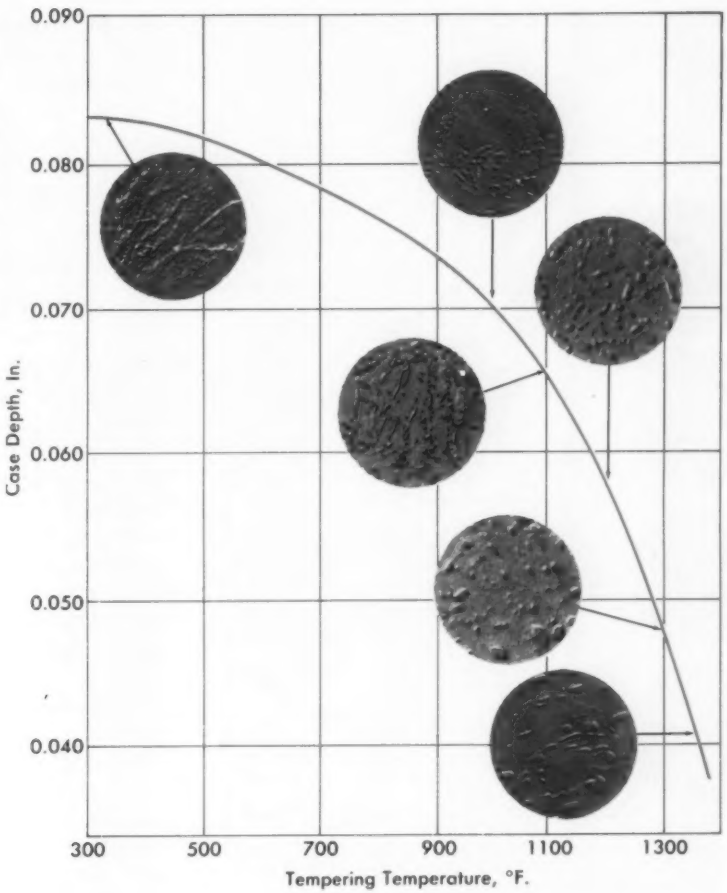

Fig. 1 – How Microstructure Responds to Tempering Temperature. Samples were quenched, tempered and induction hardened. (The insets illustrate the resulting microstructures.) Higher tempering temperatures coarsened the carbides which dissolved more slowly as evidenced by a drop in case depth. 8000 ×

little difficulty in obtaining a specified case depth with the desired hardness throughout. On the other hand, in the induction hardening grades of steel, carbon usually does not exceed 0.50%. Therefore, full use of the available carbon must be realized if the highest quality case is to be obtained. It is at this point that the problem begins and the role of structure becomes so important.

At the risk of stating the obvious, it should be emphasized that, regardless of the amount of "available" carbon present, it is the amount of carbon that actually goes into solution that determines the hardness obtained in the case. Similarly, the case depth, or pattern, is restricted to the depth at which this solution of carbon takes place. Thus, the approach to the problem seemed to be primarily that of increasing the solution rate of the carbon mechanically, that is, by putting the carbides in a more finely divided state. This increases the total surface area so that the diffusion of carbon would occur rapidly and on as many fronts as possible during the brief time at the austenitizing temperature.

In the Actuator Department at Saginaw Steering Gear, the materials most commonly used for induction hardening are S.A.E. 4145, 4150, and 6150. For general applications, the stock is first "core developed", or hardened and tempered, to a hardness of Rockwell C-20 to 25. This structure is called sorbite. Its microconstituents consist of spheroidal carbide in a matrix of ferrite, which is a result of austenitizing the steel, quenching to martensite, and then tempering to release carbon as spheroids of carbide. It is during the tempering operation, where the spheroids are formed, that the matter of structure becomes critical. To reveal the actual difference between carbide particle sizes as found in various hardened and tempered structures, and to show the effect which these structures have upon induction hardening results, two graphs and a series of electron photomicrographs are included here.

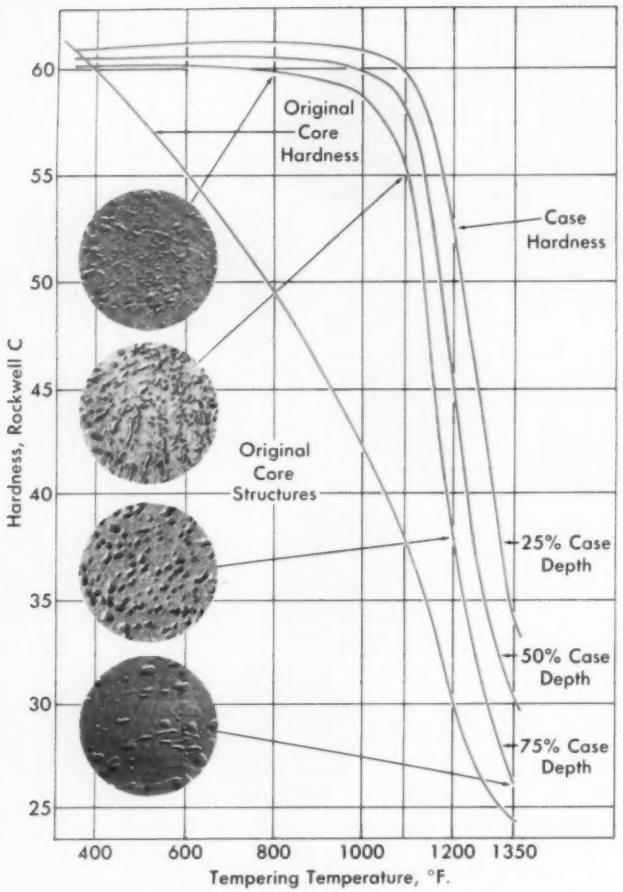

Fig. 2 — How Case Hardness Varies With Prior Tempering Temperatures. At 1200° F., the maximum slope of the curves, a critical carbide particle size was formed. Below 1200° F., the hardness of the case is greatly improved. 8000 ×

Test Procedure

The induction heating device used for this experiment was of the motor-generator type, with a frequency of 9720 cycles and a capacity of 250 kw. An induction heating coil having an integral oil quench was designed with a heat zone 1 in. in length and an inside diameter of 1½ in. Samples were made of fine-grained, S.A.E. 4145 H steel tubing, with a Jominy hardenability of Rockwell C-59 at 2/16 in. The samples were ground to an outside diameter of between 1.236 and 1.239 in. and cut to 1-ft. lengths.

To obtain an accurate comparison of results, all variables in the preparation of the samples for induction hardening were held constant with the exception of the final tempering operation. All samples were first normalized at a temperature of 1650° F., austenitized at 1550° F., and oil quenched. After being stress relieved at 325° F., the samples were given individual tempering treatments at temperatures ranging from 325 to 1350° F., for 1 hr. each.

Fine Carbides Preferred

Figure 1 illustrates the relative ease with which the various structures respond to induction hardening. In this graph the tempering temperatures used for core development are shown along the abscissa. It is evident from the electron photomicrographs that the carbides become progressively coarser with increasing tempering temperatures. The constant power setting used in this experiment resulted in a certain case depth for each structure. The curve reveals that, as the carbides become finer, the structure becomes more responsive to induction heating, as indicated by the progressively deeper case penetration. From this, it may also be inferred that the coarser the carbides, the greater the heat input must be to obtain a given case depth.

In Figure 2, the lower curve shows the relationship between tempering temperatures for core development and their corresponding hardnesses. The lower the tempering temperature, the higher the hardness, and the finer the carbides. As the tempering temperature increases, the carbides become coarser, and the hardness drops. The set of three curves, which shows case hardnesses at various depths, indicates the "quality" of the induction hardened case as obtained from each core-developed structure. ("Quality", as used here, refers to the hardness throughout the case, with microhardness readings taken at 25%, 50% and 75% depths.)

Importance of Tempering Temperature

Again referring to the set of three curves in Fig. 2, it can be seen that spheroidal structures developed at temperatures higher than 1000° F. rapidly lose their responsiveness to heat as indicated by the increased drop in hardness within the case between the 25% and 75% depth readings. This can be explained by the fact that, beyond 1000° F., each additional increment of heat has a greater coarsening effect upon the carbides than does an equal increment of heat below 1000° F. At 1200° F., the hardness drop

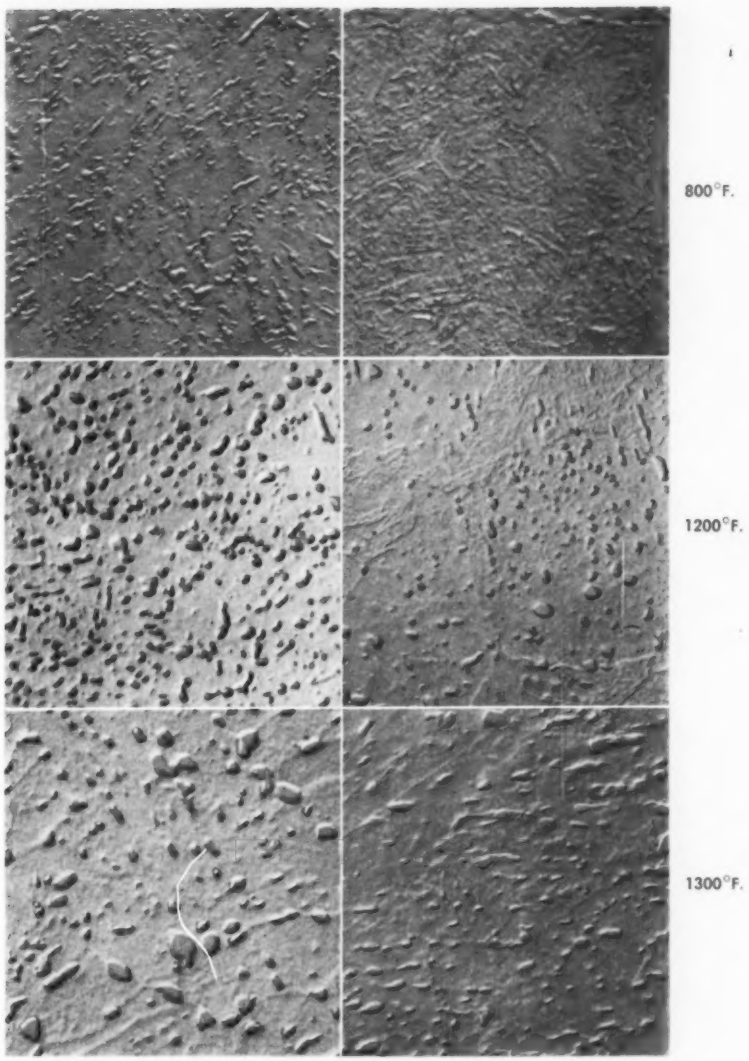

Fig. 3 – These Micrographs Show How Carbide Size Affects Solution Speed During Induction Hardening. Tempered structures (temperatures are listed) are shown on the left; tempered and induction-hardened structures, on the right. Small carbides (800° F.) dissolve completely; medium carbides (1200° F.) dissolve partially; and large carbides (1300° F.) dissolve only slightly. 12,000 ×

between the 25% and 75% depths is greatest, for at this point the slope of the curves has reached a maximum. Apparently, for this particular grade of steel, this temperature has formed a critical carbide particle size insofar as the response of hardened and tempered structures to induction heating is concerned. For it is evident from the three curves that, if tempering temperatures are higher than 1200° F., then the quality of the entire case will be appreciably lowered. On the other hand, at temperatures lower than 1200° F., the entire case depth improves considerably.

The electron photomicrographs shown in Figure 3 illustrate the ease and the reluctance with which these carbides go into solution. Original core structures developed at tempering temperatures of 800° F., 1200° F., and 1300° F., are each compared with a photomicrograph showing the extent to which the carbides have transformed in the case as determined at the 75% depth. Note that a nearly complete solution of carbides has occurred in the case obtained from the structure tempered at 800° F. In the cases obtained from the structures tempered at 1200° F., and 1300° F., there are increasingly greater amounts of undissolved, or untransformed, carbides. In Fig. 2, note the relative hardnesses of these three positions along the curve representing the 75% case depth.

It should be remembered at this point that

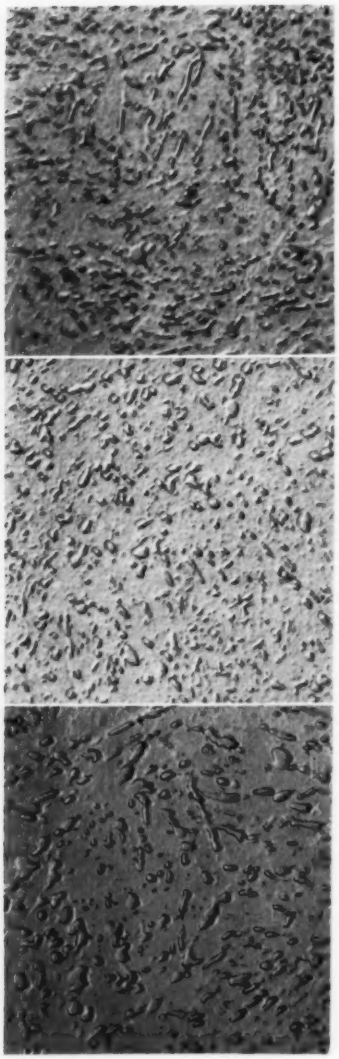

Fig. 4 – How Carbides Coarsen With Increasing Tempering Times. These structures were formed during tempering at 1100° F. for 1, 3 and 6 hr. Progressive coarsening of the carbides as tempering time is increased is evident. 12,000 ×

the case hardness values of the set of curves in Fig. 2 are based on an arbitrary heat input, without regard to any case specification. Actually, higher intermediate hardnesses could be obtained by increasing the voltage or time or both. However, the relative responsiveness of these structures to heat will still exist. In other words, it will be more difficult to obtain case quality from a structure developed at 1200° F. (and above) than from structures developed at lower temperatures. Results are borderline, or worse, when a minimum hardness of Rockwell C-58 is desired. The problem becomes more difficult when surface contours and case pattern specifications must be considered. For instance, when working with structures having coarse spheroids, so much heat is required to dissolve the carbides to the depth required, that it is often impossible to obtain the desired hardness and pattern without causing grain coarsening and melting.

Effect of Tempering Time

In the heat treatment of steel for induction hardening, there is another factor, besides the tempering temperature, which will cause carbides to coarsen, and that is the total time of tempering. In Fig. 4 are shown three structures which were hardened and tempered at 1100° F. for periods of 1 hr., 3 hr. and 6 hr., respectively. It is clearly evident that carbide coarsening has occurred. In fact, 6 hr. at 1100° F. has produced a structure similar to that obtained by tempering at 1200° F. for 1 hr. This carbide coarsening effect, the result of increased tempering time, would be even more severe at higher temperatures. If tempering cycles are inconsistent, then, with other factors considered, it could explain why different lots of steel parts do not seem to react in the same manner as with previously determined settings of voltage and time.

Summary

In summary, it was shown that microstructures containing the finest spheroidal carbides respond the best to induction hardening. With such microstructures a harder and more uniform case pattern is obtained. Also, for any specified case hardness and pattern, a lower heat input is required, thus eliminating grain coarsening and melting.

There exists a critical carbide particle size in the sorbitic (hardened and tempered) microstructure as used for induction hardening. For S.A.E. 4145 steel, as an example, this critical carbide size is formed at 1200° F. With tempering temperatures lower than 1200° F., the response of the microstructure greatly improves. With temperatures higher than 1200° F., the response diminishes. Also, longer tempering cycles tend to coarsen the carbides, which cause the microstructure to become somewhat less responsive to induction hardening.

Fig. 1 – How Titanium Sheet Is Charged Into the Hot Forming Furnace. No protective atmospheres are needed because the heating is always under precise control. Also, contaminating air is largely kept from inside the furnace by stainless steel curtains in the vestibule and adjustable entry doors

Modern Heat Treatment

Temperature Control in Titanium Processing

*By P. C. BARR**

For processing, titanium should be heated only to the lowest possible forming temperature. Though protective atmospheres are not needed under these circumstances, room air should be kept from inside the furnace as much as possible. Precise temperature control is also necessary. This article describes custom furnaces and heating procedures for processing several titanium alloys. (G-general, J23, 1-55; Ti-b)

TITANIUM IS A RELATIVELY NEW METAL, few companies are making it today. However, as time goes on, production is expected to increase greatly because of the excellent combination of properties that titanium has to offer. Since it is almost as light as aluminum, resists most oxidizing media, and withstands operating temperatures between 300 to 850° F., it has become a vital material in our rocket and missile program. However, one factor which inhibits wider use of the metal is the difficulty of fabrication. Titanium is hard to form in a cold

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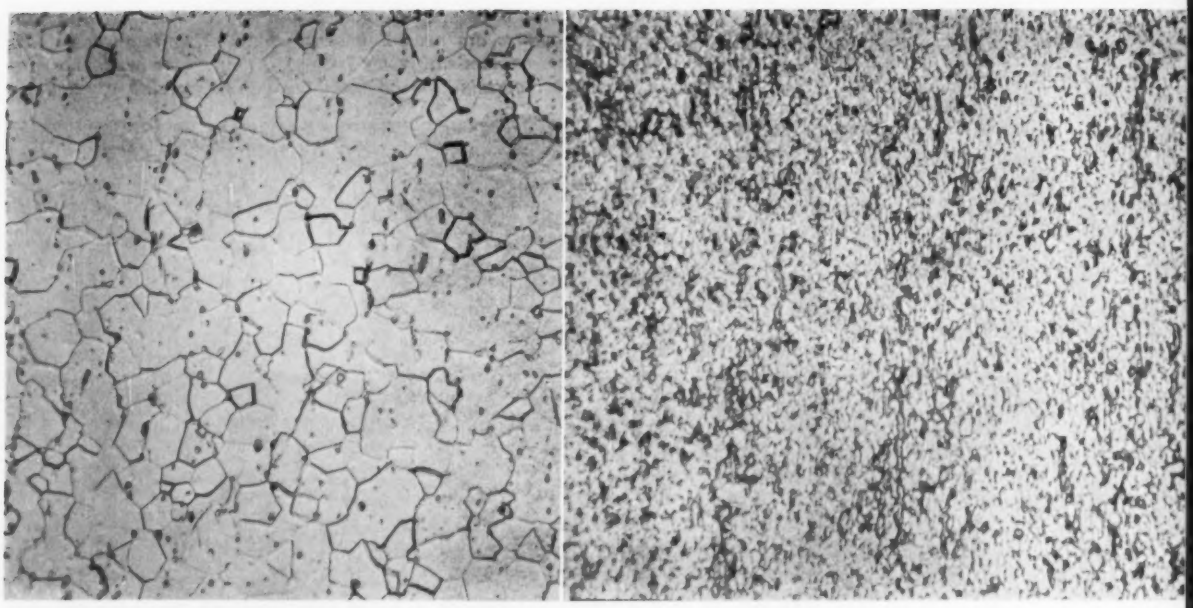


Unalloyed Titanium

6 Al, 4 V Titanium

Fig. 2 – Typical Microstructures in Mill-Annealed Titanium and Three of Its Alloys. Alpha is apparent in the unalloyed titanium; alpha and retained beta in the 6 Al, 4 V titanium alloy (annealed at 1300° F.); fine-grained structure in the 4 Al, 3 Mo, 1 V titanium alloy (annealed at 1650° F.) and equiaxed grains in the 5 Al, 2.5 Sn titanium alloy (1350° F.). All structures were revealed by an etchant consisting of 2% HF in saturated oxalic acid; 250 × except for 4 Al, 3 Mo, 1 V titanium alloy which is 50 ×

state, embrittles easily, and is susceptible to contamination by atmospheric gases. To use titanium, then, these problems must be solved.

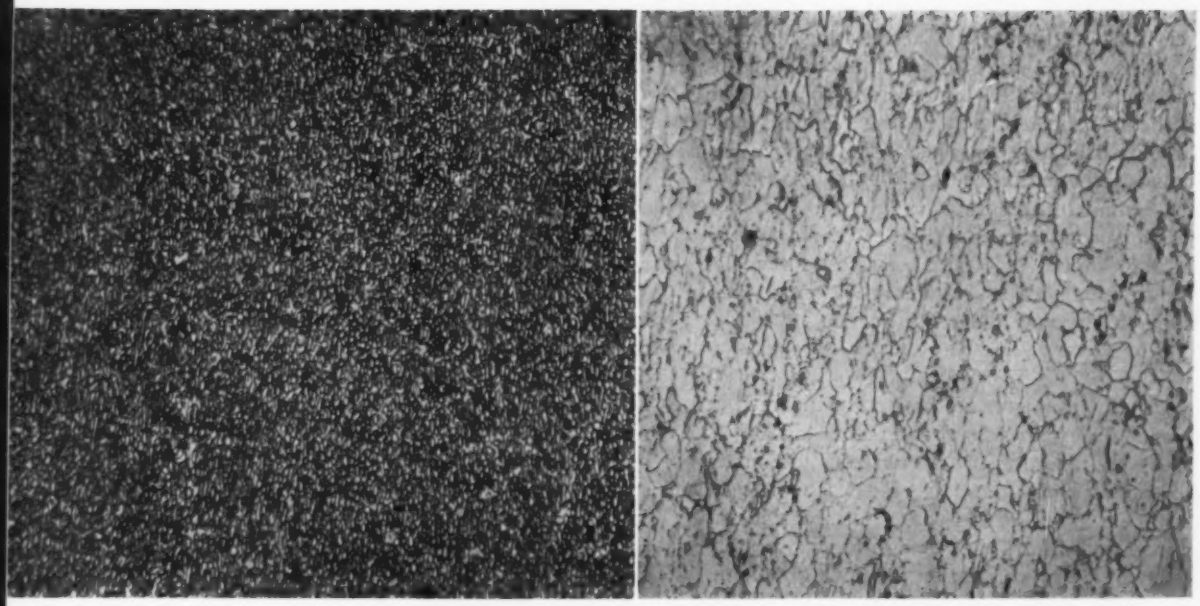
Heat Control Is Vital

Because heat is an important factor in all stages of titanium production, it must receive particular attention. Several major considerations enter into heat control. Unalloyed titanium requires about 30% more energy to hot work than does carbon steel; even higher energies are required to process the alloys, particularly those containing aluminum. As a general rule, the higher the aluminum content, the higher the processing temperature and energy required.

Titanium is more difficult to hot work than steel primarily because of three factors. First, titanium must generally be fabricated at lower temperatures (1900° F. or below) than steel. At the temperatures required for forging, oxygen and nitrogen react rapidly with the surface. Not only is a heavy scale formed, but the gases diffuse into the metal at an increasingly higher rate as the temperature increases. Lower temperatures are also necessary to avoid the "beta embrittlement", a defect which occurs when titanium alloys are heated above the beta transus and if sufficient work has not been performed below this temperature. Table I lists the beta transus temperatures for the commercial alloys.

The second factor that makes titanium more difficult to hot work is its crystal structure. The two allotropes, alpha and beta, have a close-packed hexagonal and a body-centered cubic structure respectively. This combination of structures is believed to have fewer slip systems than does austenite, the structure of steel at rolling temperatures. As for the third factor, titanium has a high coefficient of friction when it is in contact with other metals.

In short, all of these drawbacks must be compensated for when heating titanium for forming. Though other fabricators have different solutions, we have found that the best method of reducing surface oxidation is to use the lowest possible processing temperature (recommended for the particular grade involved). Then, we shape the titanium quickly with light, fast reductions. This means that the metal must be precisely and uniformly heated for



4 Al, 3 Mo, 1 V Titanium — *5 Al, 2.5 Sn Titanium*

forming. In brief, the major factor in titanium production is strict temperature control from beginning to end.

Special Furnaces Needed

Since titanium is such a difficult metal to process, the mill equipment must usually be built to order. Of the furnaces in our plant, all of which were selected for their temperature-performance qualities, three – the two hot forming furnaces and the annealing furnace – are of particular interest. All are of the roller-hearth type, and were built for us by the Electric Furnace Co. Installed in 1957, they have been used constantly since that time.

Hot Forming Furnaces

These furnaces, which are designed for operation between 1300 to 1950° F., can be maintained within ±10° F. of any given temperature as the alloys are rolled. No controlled atmospheres are needed since very little room air is allowed to enter. To accomplish this, hanging curtains made of stainless steel are set in the charging vestibule through which the titanium passes initially. Since these curtains are flexible, they do not impede the travel of the metal. Also, all doors are adjustable for minimum clearance; they can be set for each run so that the material just clears their lower edges as it enters the furnace.

The two furnaces, which are identical and may be used interchangeably, are about 60 ft. long and 10 ft. wide. Set up side by side, each has a charging table, charging vestibule, two-zone heating chamber, and runout table. A transfer car at the discharge end (see Fig. 1) is connected to a gravity return conveyor that

Table I – Temperatures for Processing Commercial Titanium Sheet Alloys

Alloy	Beta Transus★	Rolling Temperature†
Ti-55A‡	1685° F.	1300 to 1400° F.
Ti-75A‡	1740	1300 to 1400
Ti-100A‡	1770	1300 to 1400
Ti-140A‡	1525	1400 to 1500
Ti-155A‡	1775	1650 to 1750
4 Al, 3 Mo, 1 V titanium	1765	1600 to 1700
5 Al, 2.5 Sn titanium	1925	1775 to 1875
Ti-5Al-4FeCr‡	1740	1575 to 1675
6 Al, 4 V titanium	1825	1675 to 1775
8 Mn titanium	1485	1300 to 1400

★±15° F.

†The actual rolling temperature selected within these listed ranges depends on the required thickness, final processing, and whether the material is to be subsequently heat treated.

‡Ti-55A, Ti-75A, and Ti-100A are commercially pure grades; Ti-140A contains 2 Fe, 2 Cr and 2 Mo; Ti-155A contains 5 Al, 1.5 Fe, 1.4 Cr and 1.2 Mo; Ti-5 Al-4 FeCr contains 5 Al, 2.75 Cr, and 1.25 Fe.

services both furnaces. Each heating chamber is 34 ft. long, and is divided into two automatically controlled temperature zones. The first zone is heated by 20 heating elements (gas-fired, radiant-tube type) located both above and beneath the roller hearth. In this zone, the top temperature is 1850° F.

The second zone can be heated electrically to a maximum of 1950° F. by cast alloy elements mounted in refractory material both above and below the roller hearth.

Processing the Alloy

Usually, all ingots are pressed or bloomed at temperatures anywhere from 100 to 200° F. above the beta transus. In this zone, the material is plastic enough so that the coarse-grained, dendritic structure can be deformed without intergranular surface cracking. It is absolutely essential, however, that the finishing operation, whether it be for 8-in. billets or 0.020-in. thick sheet, be carried out below the beta transus.

The alloys are processed individually, or in packs made up of layers of titanium sheets between sheets of steel, the smallest packs being 16 by 16 in., while the largest sheets are 52 by 60 in. Pack thicknesses range from 2 to 0.5 in.; sheets as thin as 0.020 in. can be rolled.

After the sheets are heated and soaked at the recommended temperatures, they move rapidly to the rolling mill for reduction. Quick, light passes are employed. When the desired thickness is reached, the sheets travel to the annealing furnace.

Annealing Furnace

With few exceptions, the all-electric annealing furnace parallels the hot forming furnaces in design. There are no pressure or atmosphere controls, the emphasis being, again, on precise temperature control.

Approximately 83 ft. long and 9 ft. wide, the furnace includes a charge table, charge vestibule, three-zone heating chamber, and runout table. Hearth rollers are located on 6-in. centers, and drive equipment is similar to that on the hot forming furnaces.

Material is processed in single rows of sheet only. Material thickness varies from 0.187 to 0.020 in. and the largest sheet is 52 by 144 in. The heating chamber is divided into three automatically controlled temperature zones, the first two zones being 13½ ft. each in length. A third zone, separated from the other two zones by a 9-in. refractory baffle, is 16½ ft. long.

The annealing furnace operates from 1000 to 1670° F., depending upon the material being run. After being annealed (this operation stress relieves and conditions), the material is air cooled or water quenched as desired.

Complete Controls Provided

To assure temperature uniformity, these three furnaces are fully controlled. In addition to mechanical controls which are integral with the equipment, an observer is continuously on hand to see that the proper temperatures are reached and maintained. The observers use portable pyrometers as well as the furnace instruments to monitor the various temperatures. Supervising the operators, the observers have the authority to reject material on the spot if it does not conform to temperature specifications.

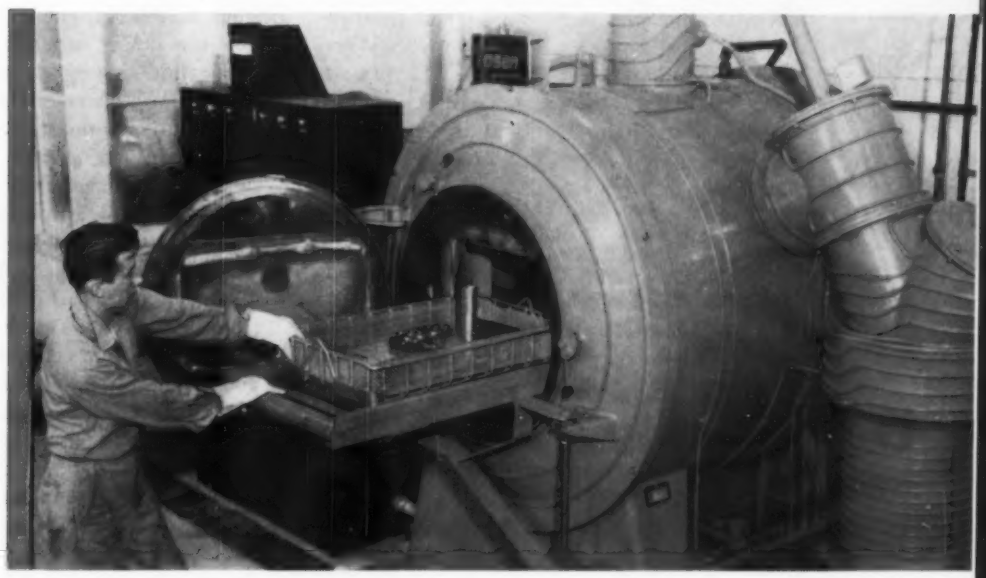
Quality Control Is Essential

The process department, to which these observers belong, is the key department in establishing and maintaining high standards in all heating operations. Though accuracy and control are, of course, important in all plants, the emphasis placed on these two conditions in ours is so strong that 15% of the floor space is devoted to laboratory facilities, and 10% of the employees are engaged in quality control activities. Cycle temperatures, times, pressures, and other specifications are set up as they apply to all operations. Rigid adherence to established procedures is enforced.

Physical, chemical and metallographic checks are also routine procedure for the process department on all alloy batches run through the furnaces. Each sheet is checked for tensile, yield, elongation and bend properties. Chemical and metallographic tests are also made on sheets from top, middle and bottom ingot locations. As typical examples, the photomicrographs shown in Fig. 2 illustrate the structures obtained when titanium and three of its alloys were mill annealed.

In conclusion, close control in all phases of operation is vital when producing titanium. In our plant, the furnaces function as precision instruments at strategic stages in the production of titanium. They provide the exact temperatures which are needed to produce the desired properties in both commercially pure titanium and titanium alloys.

Fig. 1 – Placing a Load in a Vacuum Heat Treating Furnace. After the technician closes and seals the door, he will set the controls for automatic heating, soaking and inert-gas quenching. The furnace is unloaded and recharged when room temperature is reached. Shown at the side is the vacuum pump



Modern Heat Treatment

Heat Treating in a Vacuum

STAFF REPORT

Vacuum heat treating has much potential for producing parts which meet critical hardness, tolerance and surface finish requirements. In an eastern heat treating shop, a vacuum furnace is now being used successfully to anneal, braze, and harden a wide variety of steels and other alloys from A.I.S.I. 1010 to PH 15-7 Mo, including a number of tool steels. (J-general; ST, SS, TS)

FOLLOWING SUCH PROCESSES as vacuum melting, vacuum degassing, and vacuum brazing, vacuum heat treating has now moved out of the laboratory and into the shop. Specifically, a new vacuum heat treating and brazing unit is now in daily operation at Commercial Metal Treating, Inc., in Bridgeport, Conn. According to the company's president, Michael Kober, "It is in almost constant use in heat treating a wide variety of steels – from annealing A.I.S.I. 1010 to hardening PH 15-7 Mo and several grades of tool steels of the air-hardening types." Among its advantages are safety (no explosive atmosphere is present), simplicity of operation (once the door is closed on the charge, all operations are automatic), and consistency of product (virtually no parts have been rejected because of property variations).

Though the unit is somewhat more expensive to operate than other heat treating devices of like capacity (because bottled argon and nitrogen are employed for cooling), Mr. Kober feels that the advantages more than compensate for the added cost. As he puts it, "When you need the best results, only the best processing equipment is really economical. The higher initial cost of vacuum heat treating is more than offset by lessened rejects and longer service life of treated parts."

Metallurgy of Vacuum Treating

Metallurgically speaking, vacuum heat treating is fundamentally different than heat treating in an atmosphere. In the former, dissociation of compounds takes the place of chemical reactions between elements and gaseous compounds. Let us cite a specific example of the basic difference: When stainless steel is treated in a hydrogen atmosphere, the hydrogen reduces oxides on the surface but has no effect on other contaminants (such as gases) which may be present in the surface zone. If stainless steel is heat treated in a vacuum furnace, however, not only will the surface oxides be removed (by dissociation of the oxide) but the nitrogen, hydrogen and dissolved oxygen will also go. Thus, a purer, more closely controlled product will result.

There are other metallurgical advantages to vacuum treating. For instance, there is no danger of carbonitriding, carburizing, decarburizing, nitriding, siliconizing, sulfurizing, or hydrogen embrittlement. Since contaminants such as oxide films are removed in a vacuum, work emerges exceptionally bright and with a minimum of distortion. Though there is no difference in the microstructures produced by atmosphere and vacuum heat treatment, impact strength and ductility of material treated in vacuum can be higher than that of metal processed in an atmosphere because the occluded gases are also removed.

Operating the Unit

As Fig. 1 illustrates, the unit, which was built by Ipsen Industries, Inc., Rockford, Ill., is easily managed by one man – all he does is charge the furnace and set the controls to follow the prescribed sequence for the heat treating cycle of the alloy being processed. For instance, to heat treat saw blades made of A.I.S.I. A2, a typical part that has been processed in the unit, they are charged and the furnace controls are adjusted to heat them at 1850° F. and cool them to room temperature with circulating nitrogen. Strictly speaking, the controls are set so that the load will be at room temperature when the charging door is open; therefore, the time for cooling depends on the load size.

For automatic operation, the water valve to the cooling water manifold is first opened. (All controls interlock with a water-pressure safety switch.) Next, all manual control switches are turned off and the selector switch is set for automatic operation. After the desired temperature and the time "at heat" are set, the "fast cool" timer is adjusted to control the quenching cycle. Finally, the load is placed in the furnace, the door is closed and sealed, the "start" button is depressed, and the furnace goes through the desired sequence.

This automatic routine begins when the furnace is evacuated to the desired vacuum pressure; then the charge is heated and soaked at the indicated temperature. During the cooling cycle, the gas regulator maintains a slight negative pressure to insure tight vessel seals. For rapid cooling, a 3-h.p. fan drives the gas (nitrogen or argon) down the inside wall of the vacuum shell, up past the bottom opening in the chamber, and through the work at a rate of about 2500 ft. per min. After the process is finished, a signal light flashes to indicate that the charge is cooled and that the unit is ready for another cycle.

Details of the Furnace

Perhaps some information concerning design features would be of interest. Briefly, the unit is composed of a roller-hearth furnace, a cooling fan, and a simple pumping system. The vacuum chamber, which encloses the furnace and fan, has dished end covers. A hinged and dished charging door, sealed with a rubber "square" ring is unitized with the front cover. Since the only other entries to the vacuum shell are for electric power lead-ins, a sight port, a thermocouple junction, and a cooling gas inlet, the leak rate is quite low – less than 10 microns Hg per hr. At this rate, according to our calculations, at least nine years would be required for the unit to rise from 1 micron to atmospheric pressure!

The furnace illustrated in Fig. 1 has an input of 62 kw. and a 24 by 36-in. hearth with a 12-in. work clearance. It is heated by low-voltage tubular elements (graphite) placed above and below the work chamber.

In the vacuum system, gases and vapors are removed from the sealed vessel by a mechanical vacuum pump (gas-ballast, rotary-piston type) coupled with a three-stage, oil-vapor diffusion pump. To measure the degree of vacuum, both an Alphatron ionization gage and a thermocouple gage are employed, the first being used primarily to determine the operating pressure within the vessel. Although the thermocouple-type gage serves this function as well, it also provides a safety factor since it can be set to turn off the heating elements if pressure rises over 1000 microns Hg or any preset pressure.

What the Equipment Can Do

This unit, though simple in operation, is quite versatile. With it, almost any type of heat treatment can be performed on a wide variety of metals and alloys. For example, the unit has been used to harden stainless steels (such as Type 410, 416, 420 and 440), tool steels (including A2, A6, D2, H11, H13 and M2), and precipitation-hardening steels (PH 15-7 Mo in one instance). Only those steels that must be hardened by liquid quenchants cannot be processed satisfactorily in the unit. While fairly rapid cooling rates can be achieved by blasting inert gases through hot steel, these rates will not equal those which can be attained by salt baths, oil, water, or brine. However, this limitation is of little consequence since there are a great number of steels which can be air quenched. In fact, these air-quenching grades could not be processed in liquid mediums anyway – they would be very apt to distort and crack if they were.

Among other items, the vacuum heat treating unit at Commercial Metal Treating has been used for processing die blocks made of several tool steels. For example, the company has treated die casting dies made of H13 (austenitized at 1850° F. and quenched in nitrogen to Rockwell C-56 to 57), die blocks of A6 (austenitized at 1550° F., and quenched in nitrogen to Rockwell C-63), and mold cavity inserts of D2 (heated to 1400° F., soaked, raised to 1850° F., soaked, and quenched to C-63 in nitrogen).

Figure 2 illustrates a few of the types of parts that have been processed in the vacuum unit. Parts for the shaving head of an electric razor will be recognized; they are made of an air-hardening stainless steel. The manufacturer of these razors prefers vacuum treatment because it is able to maintain precise dimensions in the hardened cutters.

Fig. 2 – Typical Parts Which Have Been Heat Treated in the Vacuum Unit. Note the cutters for an electric shaver; these parts require good hardness, close tolerances, and an attractive, bright surface. Vacuum heat treatment provides all three needs

With this unit more than one material can be processed at the same time. In one typical example, it was used for annealing the teeth of welded saw blades, the teeth consisting of A.I.S.I. M2 and the backing of A.I.S.I. 6315. The unit can be used for brazing, too – engineers at C.M.T. have brazed Type 316 bushings to Type 416 shafts.

In Summation

To sum up the experiences of those who have employed vacuum heat treatments for their parts, most of them feel that the improved properties and lower rejection rates compensate for the added expense of this type of processing. In some instances, over-all costs are lowered because the finished surface is extremely clean and free from distortion. As a result, machining costs are minimized. For example, one manufacturer could machine its parts to closer tolerances before treatment thus leaving less material to be removed by costly grinding after treatment. Formerly, they left 0.008 to 0.009 in. on the surface for grinding; now, they machine down to within 0.005 in. of the desired finishing dimensions.

With such favorable reports from users of vacuum processed parts, it would seem that vacuum heat treating, though still in its infancy, will soon take its proper place in the ranks of important heat treating methods. According to users, it is helping to cut production costs, reduce processing problems, and last, but not least, keep customers happy.

A Method for Strengthening Semiaustenitic Stainless Steels

*By D. C. LUDWIGSON**

Both the formability and strength of a semiaustenitic stainless steel can be improved to a degree by mild deformation followed by a stabilizing heat treatment. (Q27, Q23q, J-general; SS)

THE SEMIAUSTENITIC STAINLESS STEELS, such as 17-7 PH and AM 350, offer a good combination of formability, strength, and corrosion resistance. As annealed†, they exhibit yield strengths near 45,000 psi. and elongations of about 30%. When subsequently hardened, tensile and yield strengths of 210,000 and 175,000 psi., respectively, are achieved. Furthermore, the corrosion resistance of this type of alloy compares well with that of the martensitic stainless steels.

Transformation Is Sluggish

These alloys, however, are sensitive to thermal and mechanical stabilization of austenite against transformation to martensite. Some of them, for example, will not be transformed completely to martensite by refrigeration if allowed to stand after being triggered. In addition, it has been noted that mild forming operations on triggered material decrease the extent to which it can be made martensitic by refrigeration. Although these manifestations of stabilization are detrimental, the phenomenon can be harnessed and used to improve the properties of semiaustenitic alloys to a degree. The study described shows how.

For the work, we used an alloy that contained 0.12% C, 2.2% Mn, 0.43% Si, 16.2% Cr, 4.3% Ni and 2.2% Mo. As annealed, the alloy was wholly austenitic and, therefore, soft and formable; it had a yield strength of 46,500 psi. and an elongation of 29.3%. After hardening, the alloy was martensitic. Yield and ultimate tensile strengths were 174,000 and 208,000 psi.,

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†See box on p. 80 for details of treatment, and definitions of other terms used to describe processing treatments in this article.

Table I – Effects of Various Treatments on Transformation Characteristics

Condition	Stretched	Rockwell A Hardness	Yield Strength	Tensile Strength	Elongation
Annealed	—	56.5	46,500 psi.	162,000 psi.	29.3%
Annealed and hardened	—	73.5	174,000	208,000	8.6
Annealed and stretched	1%	59.6	53,500	162,000	29.4
	3	61.9	62,500	168,000	27.5
	6	65.4	81,800	172,000	25.3
	10	68.8	115,000	183,000	19.1
	15	70.3	148,000	192,000	14.8
	20	71.0	170,000	194,000	13.4
	25	72.3	193,000	197,000	8.6
Annealed, stretched, refrigerated and tempered	0	70.0	113,000	178,000	21.4
	1	67.9	92,600	173,000	29.7
	3	67.7	98,700	169,000	29.7
	6	68.4	115,000	165,000	27.0
	10	69.0	134,000	165,000	26.2
	15	70.9	164,000	174,000	17.2
	20	72.0	190,000	193,000	6.6
	25	73.1	206,000	208,000	4.9
Annealed, stretched and stabilized	0	56.0	46,700	160,000	31.9
	1	59.2	58,000	159,000	34.5
	3	62.4	70,500	159,000	33.8
	6	65.7	92,100	155,000	35.3
	10	68.7	132,000	163,000	25.4
	15	71.0	172,000	176,000	15.2
	20	72.3	191,000	198,000	7.8
	25	73.1	208,000	210,000	3.8
Annea'ed, stretched, stabilized and hardened	1	73.4	179,000	213,000	9.7
	3	74.3	185,000	218,000	6.9
	6	74.4	185,000	216,000	7.4
	10	74.4	190,000	218,000	6.4
	15	74.4	191,000	217,000	8.9
	20	74.3	194,000	217,000	8.7
	25	74.3	189,000	215,000	10.5

Tensile properties are based on two tests; hardness is the average of 20 tests.

respectively, and the elongation was 8.6%.

In the experimental alloy, as annealed, all of the carbon is in solution, and the M_s temperature is about -100° F. Hardening begins with a trigger anneal at 1700° F. During this treatment, chromium carbide particles ($Cr_{23}C_6$) precipitate at the grain boundaries, depleting the austenitic matrix of about 0.05% C and about 0.85% Cr. Each 0.01% of carbon removed from solution is thought to raise the M_s by 26 to 30° F., and each 1% of chromium taken out of an austenitic solution is believed to raise the M_s by 66 to 75° F. Accordingly, the trigger anneal should raise the M_s by about 200° F., or from -100 to $+100^\circ$ F. (Actually, annealed and triggered material responded weakly to a magnet at room temperature, indicating that some martensite was present in the microstructure.) During the next step, refrigeration at -110° F., the structure transformed from austenite to martensite almost completely. Final properties were obtained by tempering at 850° F.

Why Stabilization Occurs

If an austenitic structure is cooled to some temperature between M_s and M_f and held at that temperature for a period of time, martensite does not begin to form immediately when cooling is resumed. This is because the martensite which appeared during the initial cooling has stabilized the remaining austenite against transformation. Martensite formed by deformation, as well as by cooling, can also cause stabilization. Previous research has shown that the stabilizing effect increases with increasing

amounts of martensite, and that, for a given martensite content, stabilization is enhanced by tempering the martensite.

According to the reaction-path theory, martensite is nucleated at minute strained regions in the austenite matrix. In these regions, the strain energy available can be added to that of the normal lattice vibrations to aid in overcoming the activation energy barrier between austenite and martensite. Adjacent regions are strained during the formation of a martensite plate so that a certain number of potential strain centers are brought almost to the energy level required to nucleate martensite. If the material is left in this condition, however, the strain centers will relax with the passage of time; this drastically reduces their potential for nucleating martensite. Since relaxation takes place more rapidly at moderately elevated temperatures than at room temperature, tempering the martensite in a structure of austenite and martensite enhances the stabilization of the remaining austenite.

Experiments Verify Theory

Table I presents the effects of various treatments on the properties of the experimental alloy. (We stretched and treated tensile test specimens to obtain these data, incidentally.) Stretching, during which martensite was formed, increased strength and hardness and decreased elongation. In like manner, refrigeration caused martensite to appear in the microstructure at all levels of prior deformation, as evidenced by the increase in the yield strength and hardness.

The data in Table I also illustrate the stabilizing effect of the martensite formed during deformation. For example, unstretched specimens could be hardened to a yield strength of 113,000 psi. through refrigeration; but specimens stretched just 1% prior to refrigeration could be hardened to a yield strength of only 92,600 psi. The martensite formed during stretching had stabilized the remaining austenite during the interval between stretching and refrigeration.

For each level of stretch from 1 to 25%, the specimens that were subsequently refrigerated, as evidenced by their greater yield strength, contained more martensite. Yet, specimens stretched as much as 15% had greater elongation after refrigeration and tempering. The tempering treatment appears to have been exceptionally effective in stabilizing the austenitic portion of mixed structures. Specimens stretched 20% or more probably contained so little remaining austenite that, even though highly stabilized, it could not contribute much toward improved elongation. The fact that tempering improves the ductility of the martensitic portion of the mixed structure, however, also enters into these comparisons. Additional tests on similar alloys confirmed these findings.

Definition of Terms

Annealed: Solution treated at 1900° F. for 10 min. and rapidly cooled in air to room temperature.

Stretched: Elongated in uniaxial tension.

Stabilized: Held at 850° F. for 1 hr. directly after stretching.

Triggered: Held at 1700° F. for 10 min. and rapidly cooled in air to room temperature.

Refrigerated: Cooled to −110° F. and held at this temperature for 8 hr.

Tempered: Heated at 850° F. for 1 hr. directly after refrigeration.

Hardened: Triggered, refrigerated, and tempered.

Better Elongation Is Obtained

Of course, the transformation of austenite to martensite during deformation reduces the steel's ductility and limits its formability. In an attempt to improve ductility, annealed samples of the experimental alloy were stretched various amounts and then stabilized at 850° F. for 1 hr. As shown in Table I, elongation increased from 29.3 (for the annealed material) to 35.3% after a stretch of 6% followed by a stabilizing treatment. Yield strength and hardness increased with the improvement in elongation. Other similar alloys having elongations of 16, 22, 27 and 34% in the solution-annealed condition exhibited maximum elongations of 21, 28, 30 and 40%, respectively, after being stretched varying amounts (up to 10%) and then stabilized.

The effects of stretching and stabilizing on material subsequently hardened are also shown in Table I. Stretching and stabilizing accounted for some improvements in strength (by about 10,000 psi.).

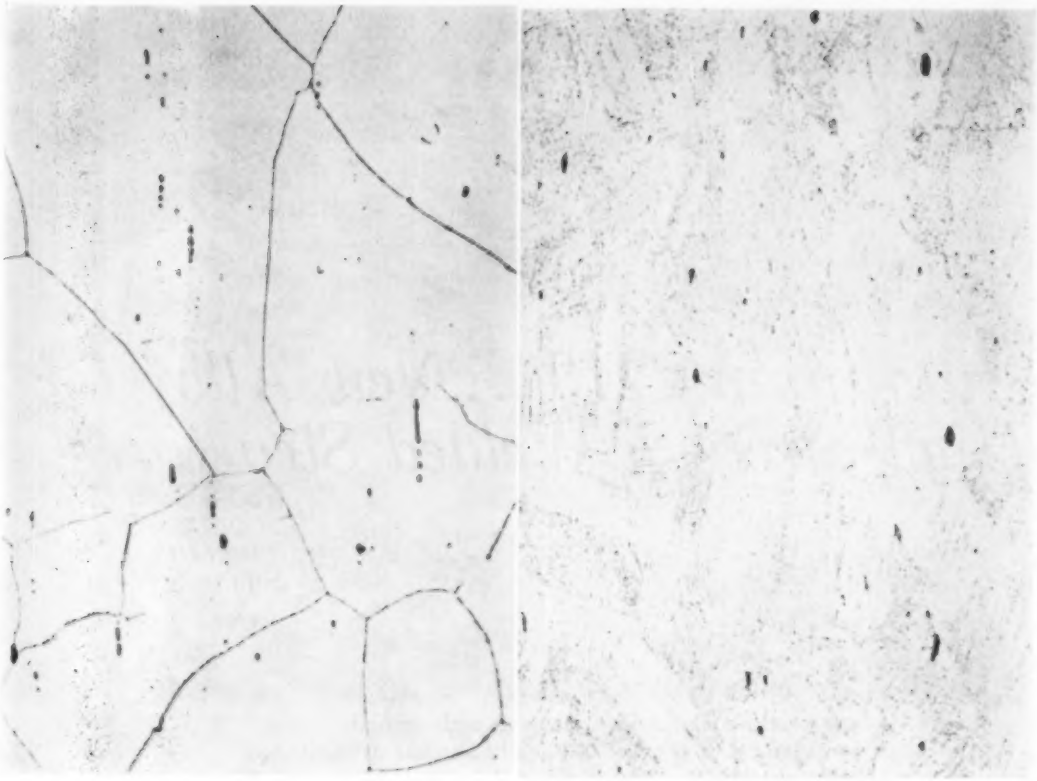


Fig. 1 – Undeformed and Deformed Experimental Steel After Being Triggered (Held at 1700° F. for 10 Min. and Rapidly Cooled in Air to Room Temperature). Specimen on left was annealed and triggered; specimen on the right was annealed, deformed 10% and triggered. Note the fine, evenly distributed carbides in the deformed specimen compared to the coarse precipitate at the grain boundaries of the other. Etchant: oxalic acid; 500 ×

Some Possibilities To Be Considered

The reason for the strengthening effect of the stretching and stabilizing treatments probably lies in their influence on the positions which the chromium carbide particles take when they precipitate during the trigger anneal. As shown in Fig. 1, carbides precipitate at the grain boundaries in undeformed material. In deformed material, however, they precipitate along the traces of active slip planes. These finely distributed particles probably contribute more to the strength of the alloy than grain-boundary carbides. It is also possible that the fine distribution of carbides in deformed material results in a more uniformly depleted austenite, and – after refrigeration and tempering – more uniformly hardened martensite.

It is expected that material stretched and stabilized prior to hardening will have better corrosion resistance than material hardened without prior deformation. As is apparent in Fig. 1, the deformed specimen exhibits no continuous paths of precipitated carbides; therefore, it is not sensitized to rapid intergranular attack. Although no tests were made to substantiate the contention of better corrosion resistance, cold work either before or after a carbide-precipitation treatment is a well-recognized, if little-used, way to combat sensitization.

In conclusion, each improvement in properties that results from stretching and stabilizing is modest, elongation of annealed material being increased by about 5% while yield and tensile strengths of hardened material are increased by about 10,000 psi. The extent of the expected increase in corrosion resistance is unknown. In total, however, these benefits may warrant the additional treatments required to attain them. With further, more intensive, research it may be possible to obtain larger improvements in strength and elongation through discovery of more effective thermal treatments.

Aluminum 2219...New Alloy for High-Strength Welded Structures

By F. R. COLLINS,
F. G. NELSON
*and I. B. ROBINSON**

A heat treatable alloy which retains its high strength at temperatures of 450 to 700° F., 2219 also has demonstrated superior weldability. Defects from fusion welding that would decrease the strength of structures made of other alloys of this type have virtually no effect on the strength of structures fabricated from 2219. Weldments perform well at subzero and at elevated temperatures.
(A-general, K9s, Q-general; Al-b)

THE FAMILIAR HIGH-STRENGTH aluminum alloys such as 2014, 2024 and 7075 exhibit outstanding mechanical properties after heat treatment, and are attractive for applications requiring a high strength-to-weight ratio. In the past, such alloys were generally joined by spot welding or mechanical and adhesive methods because attempts to fusion weld them were not successful. Alloy 2219† is the best alloy of this group for fusion welding by commercial practices. It has demonstrated high weld efficiency in all of its various tempers, under welding conditions and stress combinations that often cause decreased strength in other high-strength aluminum or ferrous alloy welds.

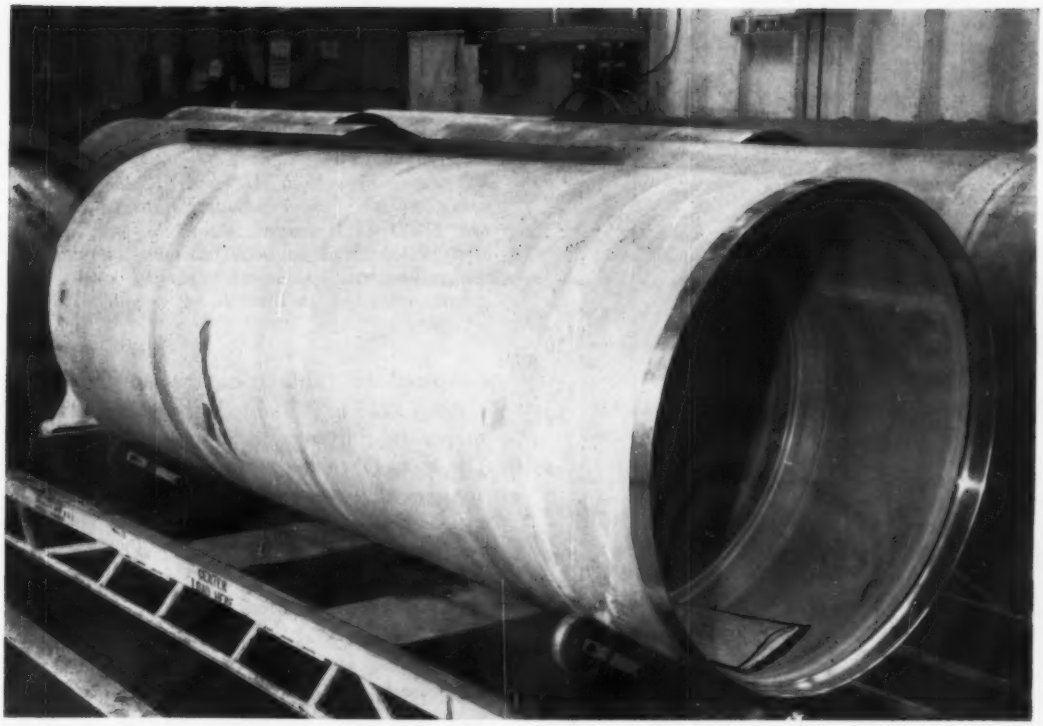
*Mr. Collins is head, joining section, Mr. Nelson is research engineer and Mr. Robinson is research engineer, Alcoa Research Laboratories, New Kensington, Pa. Part I, published in September, discussed the general characteristics, properties and corrosion resistance of alloy 2219.

†U.S. Patent No. 2,706,680.

Welding Characteristics Are Excellent

Alloy 2219 is easy to weld. Metal flow is comparable to that of the aluminum-magnesium alloys. Commercially sound welds have been obtained in sheet and plate up to 1 in. thick and techniques are being developed for thicker plate. Susceptibility to hot-short cracking is much less than in other high-strength, heat treatable alloys and compares favorably with that of the aluminum-magnesium alloys.

Weld cracking in 2219 is not influenced greatly by joint design and parent metal-filler wire dilution because their compositions are



Welded Fuel Tank for Bomarc Ramjet Made of 2219 Aluminum (Courtesy Boeing Co.)

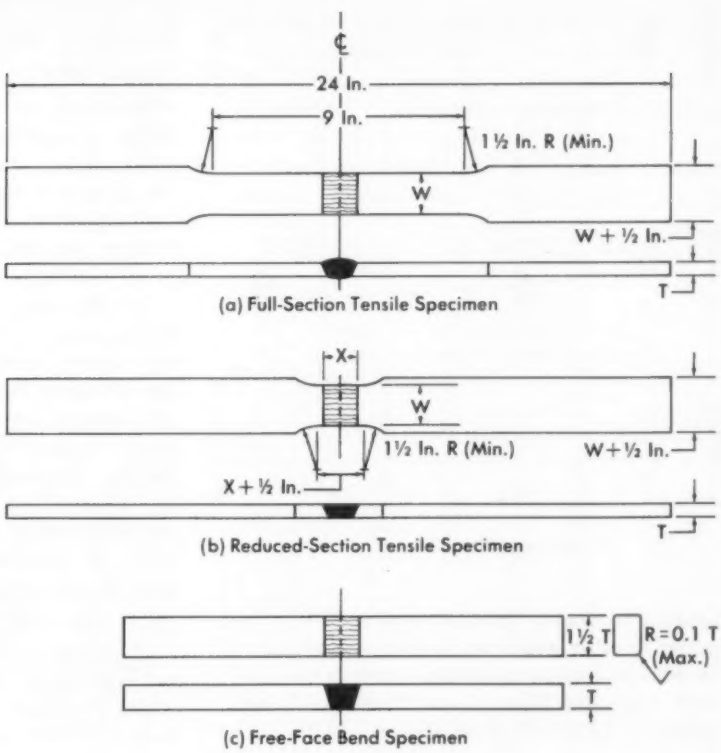


Fig. 1 – Three Types of Test Specimens Obtained From Butt (Groove) Welded Plate: (a) W = 1½ in. ± 0.01 if T does not exceed 1 in.; W = 1 in. ± 0.01 in. if T exceeds 1 in.; (b) Weld metal is machined flush with base metal. X = width of weld; notes in (a) concerning W (width) also apply; (c) Length should approximate 16T (9 in., min.)

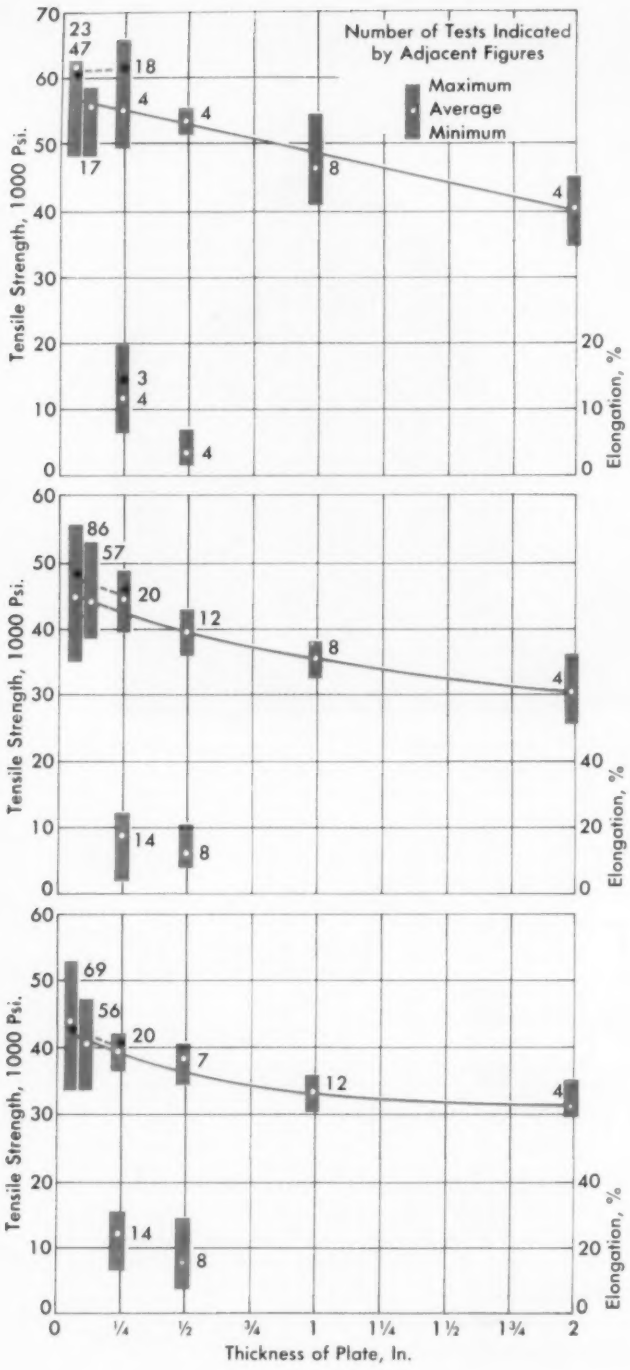


Fig. 2 – Strength and Elongation of Groove Welds in 2219-F Sheet and Plate Using 2319 Alloy Electrodes. (Top): Solution heat treated and aged to T 62 temper after welding; (center) 2219-T 31 and T 37, aged after welding to T 81 and T 87 tempers; (bottom) 2219-T 81 and T 87, as welded. White dots show both MIG and TIG welds, using an a-c. power source. Black dots are DCSP-TIG welds. Data on tensile strength obtained on both full-section and reduced-section specimens; data on elongation obtained on free-bend specimens

nearly identical.‡ In this respect 2219 is superior to other weldable aluminum alloys, such as 6061 and 2014, since they must be welded with dissimilar filler wires. The crack sensitivities of 2219 and other aluminum alloys are compared in Table I on the opposite page.

Alloy 2219 is available as sheet, plate, extrusions, and forgings in a variety of tempers. The F (as fabricated) and 0 (annealed) tempers are generally recommended for assemblies that can be heat treated and aged to the T 62 temper (solution heat treated and aged by customer) subsequent to welding. The readily formable T 31 and T 37 tempers, obtained by solution heat treating and cold working, are recommended for structures that can be aged after being welded. The fully aged tempers, T 81 and T 87, are recommended for structures where little forming is necessary prior to welding or where it is impracticable to age the completed assemblies.

Strength of Welds

Alloy 2219 is influenced less by welding conditions than are other high-strength aluminum alloys. Nevertheless, the strength of a sound weld – in any alloy – can be as low as that of the annealed temper unless suitable welding techniques are used. The best welding procedures use high travel speeds, small stringer beads, low heat input, and a quick chill.

To determine the mechanical properties of welds, plate specimens of alloy 2219 (Fig. 1) were joined using inert-gas-shielded tungsten-arc and consumable electrode processes. Tensile strength and elongation values for welds in various tempers of 2219 plate are plotted in Fig. 2. The highest strengths across the weld are achieved by reheat treating and aging to the T 62 temper after welding. Average properties of specimens heat treated after being aged are shown in Fig. 2, top. In thicknesses up to and including 0.250 in., weld strengths

‡Electrode alloy 2319 has the same composition as 2219 – 6.1% Cu, 0.3% Mn, 0.15% Zr, and 0.10% V – except for the addition of 0.15% Ti to reduce hot-short cracking.

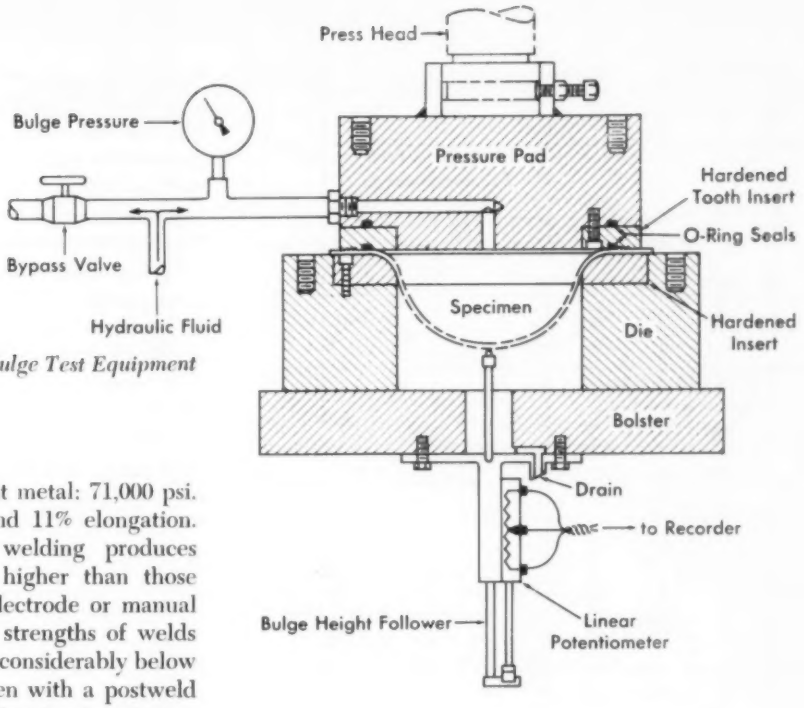


Fig. 3 – Sketch of Hydraulic Bulge Test Equipment

approach those of the parent metal: 71,000 psi. tensile, 42,000 psi. yield, and 11% elongation.

Automatic tungsten-arc welding produces ultimate strengths slightly higher than those attained with consumable-electrode or manual tungsten-arc welding. The strengths of welds in 1-in. and thicker plate are considerably below that of the parent plate, even with a postweld heat treatment. Special aging treatments can increase weld properties to about 65,000 psi. tensile, 49,000 psi. yield and 10% elongation, but these should be used only after consulting the supplier of the material since susceptibility to stress-corrosion cracking may then become a problem.

The strength and elongation of welds made in 2219-T 31 or T 37 sheet and plate, then aged to the T 81 or T 87 temper, are shown in Fig. 2, center. Figure 2, bottom, shows the tensile strength and elongation of as-welded joints in T 81 and T 87 temper material. The tensile strengths of welds in these two tempers are approximately the same for each gage.

In the thinner gages, welds made in T 31 or T 37 temper sheet (postweld aged) developed yield strengths about 80% of the tensile strength. Welds made in T 81 or T 87 temper sheet developed yield strengths of about 70% of the tensile strength. Tensile and yield strengths of the thinner gages are significantly higher when DCSP* automatic tungsten-arc welding is used. An exception is the as-welded condition, where results are about the same for all welding methods.

Significant reductions in both weight and cost can be achieved through the use of 2219, in thin gages, in place of lower-strength heat treatable alloys (such as 6061) by following the design rules outlined by H. N. Hill, J. W. Clark and R. J. Brungraber (*Proceedings* of American Society of Civil Engineers, Structural Div., June 1960, p. 101). These rules consider the reduction in strength of the weld in heat treated or strain-hardened material, and provide for taking advantage of the strength of the material in regions not affected by the heat of welding. Prior to the introduction of 2219 alloy, weight savings in the high-strength aluminum alloys could not be realized because strong, reliable welds generally could not be made.

Welded structures sometimes can be designed

*Direct current, straight polarity.

Table I – Sensitivity of Various Aluminum Alloys to Weld Cracking*

Alloy		Inches of Cracking	% Cracking
Plate	Filler		
6061	4043	1	5
5456	5556	2	10
2219	2319	4	20
5154	5154	11	55
2219	2219	13	65
2014	2014	17	85

*A T-joint, double-fillet weld specimen, discontinuously welded, was used in these tests. See "Weld Cracking of Aluminum Alloys", by J. D. Dowd, *Welding Journal Research Supplement*, Vol. 31, No. 10, October 1952, p. 448s-456s.

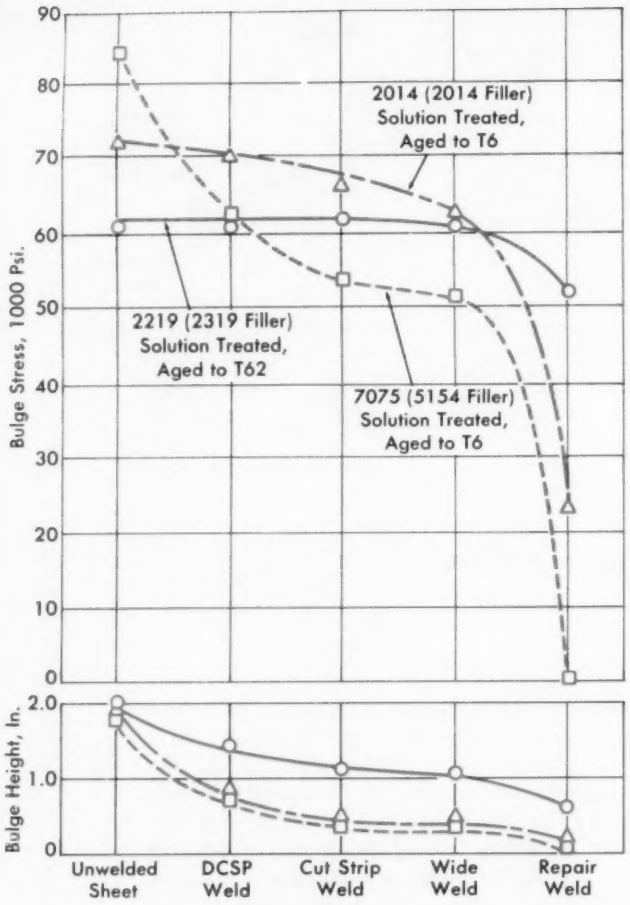


Fig. 4 – Effect of Welding Conditions on Properties Obtained in Bulge Test. All welds made on 0.064-in. sheet using DCSP-TIG equipment to determine the effects of the following welding conditions: DCSP – automatic welding and feeding of filler metal; "cut strip" – an oversize strip of parent metal, placed between the weld joint, used as filler during automatic welding; "wide weld" – wider weld bead and heat-affected zone than normal (in effect, out-of-control manual welding); "repair" – manual TIG-AC welding, with manual wire feed

so that the area to be welded is of larger cross section than the rest of the structure; this reduces the stress in the weld. Alternatively, sometimes welds can be located in regions of lower stress. Even when these design concepts are used, structures of 2219 are often superior to those of stronger but less weldable alloys.

Notes on Structural Performance

In many instances, structural performance of welds in either high-strength aluminum alloys or high-strength ferrous alloys may be difficult to predict by tensile and bend tests. To establish the structural performance of 2219 alloy, hydrostatic tests of welded pressure vessels as well as standard tensile tests of welded panels were made. For comparison, we also obtained data on 2014, a less weldable alloy.

Static tensile strengths of both 2219 and 2014 alloy panels, heat treated and aged after welding, were as high as those for the parent metal (100% efficiency). Hydrostatically tested pressure vessels of 2219 alloy showed about 75% efficiency with either welded or mechanically attached heads. Similar pressure vessels of 2014 alloy showed about 35 to 70% efficiency, depending on the tank design. Those having welded heads developed about half the strength of those with mechanically attached heads (Table II).

The tanks having welded heads were fabricated by rolling sheet into a cylinder, welding the longitudinal seam, solution heat treating, welding heat treated dished heads to the cylinder, and then aging the completed assembly. The 2219 alloy tanks always failed in the longitudinal weld; the 2014 alloy tanks always failed in the circumferential weld. The superior performance of tanks fabricated from 2219 alloy confirmed that sounder, more ductile welds were achieved.

Hydraulic Bulge Test – This is an effective method for demonstrating weld performance under certain types of biaxial loading. The simple equipment shown in Fig. 3 quantitatively measures relative structural efficiencies of welds in high-strength aluminum alloy sheet up to 0.125 in. thick and, in addition, simulates biaxial stresses and bending encountered in many welded structures. An inexpensive, flat-sheet test specimen is clamped between jaws of the tester and bulged into the lower die by pressurized fluid. Measurement of pressure and height of bulge allows calculation of biaxial stresses in the specimen at any point during the test. Bulge tests of manual welds in 2219 and 2014 alloys, Table II, ranked the alloys in the same order as hydrostatic tests of pressure vessels.

The results of bulge tests on 2219 sheet and welded sheet are listed in Table III. Welds that were heat treated and aged to the T 62 temper exhibited strengths between 85 and 100% of those of T 62 temper sheet and plate. As-welded or postweld aged assemblies achieved about 60% efficiency.

Table II – Results of Various Tests on Welded 2219 and 2014

Test	2219				2014			
	Stress, 1000 Psi.			Efficiency★, %	Stress, 1000 Psi.			Efficiency★, %
	Max.	Min.	Avg.		Max.	Min.	Avg.	
Unwelded T 6 sheet, tensile	—	—	65	—	—	—	72	—
Cross-weld tensile	70	62	68	100	75	65	72	100
Welded tanks†								
Mechanically attached heads	54	47	50	77	65	41	52	72
Welded heads	—	—	—	—	33	20	25	35
Bulge test‡	64	51	57	88	62	42	53	74

Note: All welds in 0.125-in. sheet except bulge test (0.064-in. sheet). Manual welding procedure used on all samples. Welds in 2014 made with 2014 filler, heat treated and aged to T 6 temper. Welds in 2219 made with 2319 filler, heat treated and aged to an experimental T 6 temper.

★Efficiency = maximum sustained stress/tensile strength.

†Stress $= \frac{pD}{2t}$

‡Stress $= \frac{pR}{2t}$

p = hydrostatic pressure, psi.; D = mean diameter, in.; t = thickness, in.; R = radius of curvature, in.

With presently used commercial welding practices, welds having high tensile efficiencies can be produced in alloy 2219, but welds in most other high-strength alloys will have lower efficiencies. When relatively poor welding practices are used, reheat treated welds in 2219 alloy develop better structural strength and ductility than similar welds in 2014 and 7075 alloys. This is shown in Fig. 4.

Corrosion Resistance – As discussed in detail in Part I of this series, the general resistance to corrosion of 2219 is comparable to that of other high-strength aluminum alloys (such as 2014 and 2024) when artificially aged. In addition, fabricated products and welds of 2219 are not susceptible to stress-corrosion cracking when used in the recommended artificially aged tempers (T 62, T 81 and T 87).

Attractive for many structural applications because of its desirable combination of high strength, excellent weldability, and corrosion resistance, alloy 2219 is utilized in several guided missiles, such as the Bomarc, and is being considered for use in many other situations. These include air-transportable military equipment, ground-support equipment for missiles, truck bodies and beds, and similar applications where a weldable alloy having a high strength-to-weight ratio is desired. Alloy 2219 has excellent properties at both elevated and subzero temperatures and therefore is being considered for both cryogenic and high-temperature applications. Because of its high resistance to attack by certain chemicals – hydrogen peroxide, ammonium nitrate, red fuming nitric acid, for example – 2219 is also suitable for welded storage tanks containing these active chemicals.

Table III – Average Bulge-Test Properties of 2219 Sheet (0.064 to 0.125 In.) Welded With 2319 Alloy

Test Material and Condition	Strength★, 1000 Psi.	Height In.
Sheet Specimens		
T 81 Sheet	66.8	1.91
T 87 Sheet	71.2	1.84
T 62 Sheet	57.7	1.87
Automatic Welded Bulge-Test Specimens		
As-welded (T 81 or T 87)	43.9	0.48
Postweld aged (T 31 to T 81 or T 37 to T 87)	44.2	0.48
Welded, then heat treated and aged (0 or F to T 62)	54.6	1.16
Manual Welded Bulge-Test Specimens		
As-welded (T 81 or T 87)	39.4	0.50
Postweld aged (T 31 to T 81 or T 37 to T 87)	40.7	0.44
Welded, then heat treated and aged (0 or F to T 62)	47.9	0.74

★Bulge strength $= \frac{pR}{2t}$, where p = hydrostatic pressure, psi.; R = radius of curvature, in. (calculated from bulge height); t = original sheet thickness, in.

Welding 2219 Aluminum for Bomarc Fuel Tanks

By STANLEY L. SEARS
*and RICHARD S. CRIAL**

This important application, the first for 2219, has verified the manufacturing adaptability of the alloy. No other aluminum alloy has comparable reliability in pressure-vessel applications where postweld heat treatment is required. The most readily welded of the heat treatable aluminum alloys, it has a high strength-to-weight ratio and formability comparable to 2024. (K1d, G-general, T24; Al-b, 17-57)

SUPERIOR ENGINEERING AND MANUFACTURING characteristics are required for complex thin-walled tanks used in today's space vehicles. Because of the excellent properties of alloy 2219 for pressure vessel applications, Boeing selected it for the Bomarc IM99B ramjet fuel tank. Alloy 2014 was tried and found unsatisfactory because of low weld ductility in the heat treated condition and serious difficulties with weld repairs.

To establish weld capabilities, hundreds of base-metal specimens and welded tensile and bend specimens were tested at both room and elevated temperatures. Burst diaphragm bulge tests revealed average burst pressures for welded 2219 diaphragms more than 100% higher than those of welded 2014 diaphragms and 30% higher than those of welded 6061 diaphragms. Thirty-three test tanks fabricated from 2219, 2014 and 6061 were hydrostatically tested to determine the performance capability of 2219. The difference between minimum and maximum burst pressures of the 2219 tanks was only 4.5%, whereas the variance in the 2014 tanks was 45%. Average failure pressure of the 2219 tanks was about 1% higher than that of the 2014 tanks despite the 12% higher ultimate strength of 2014.

*Research Engineers, Development Section, Aero-Space Div., Boeing Co., Seattle, Wash.

Assembly Procedure for Fuel Tank

The ramjet fuel tank is a basic part of the missile body structure. Approximately 9 ft. long and 35 in. in diameter (Fig. 1), it is of rolled-sheet construction, with roll-forged rings at the critical wing and ramjet engine attachment points and at the head-to-shell transition areas. The machined rings of 2219 are ultrasonically,

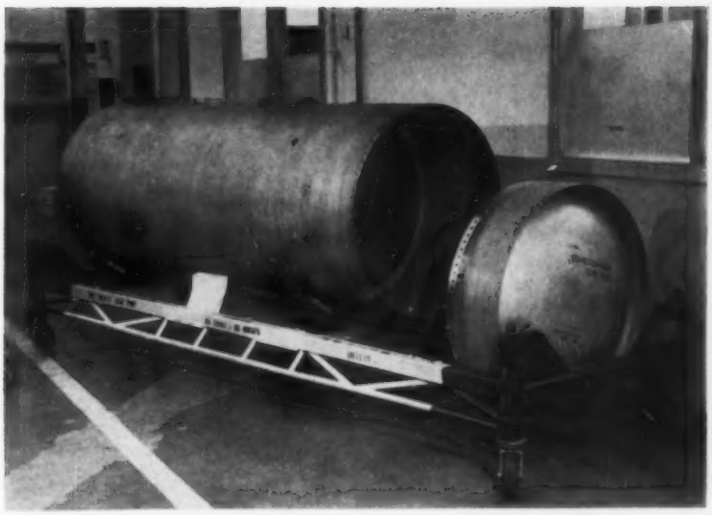


Fig. 1 – Ramjet Tank Showing Completed Tank Exterior With Bolted-On Fairing Attach Points and Wing Attach Location

Fig. 2 – Chromium-Plated Backup Tool for Fuel Outlet Fitting Weld. Micarta centering plug prevents damage to fitting threads. Groove transmits protective gas

radiographically and penetrant inspected before they are welded to the shells. After rolling, the shells are chem-milled, then longitudinally welded and trimmed to length. Between 20 and 45% of the original thickness (0.160 and 0.250 in.) is chem-milled from selected shell areas for weight reduction. A total diametral allowance of 0.080 in. is added for shrinkage during welding and heat treatment. To insure roundness and part fitup, a Grotnes hydraulic sizing machine is used.

Semielliptical tank heads are draw-formed from 0.100 and 0.120-in. thick sheet and trimmed to fit the roll-forged and machined Y-rings. The 0.100-in. thick aft-head is center bored for a 6-in. diameter fuel outlet fitting. Held on a chrom ı-plated backup tool (Fig. 2), the outlet fitting and aft-head are welded together from the outside in the downhand position on a rotary positioner. This backup tool has minimized weld defects, which could often be traced to the overlapping of the weld tail-out and the weld start. These defects were caused by oxidation during the weld start and by entrapment of air or gas at the point of overlap. The groove in the backup allows the use of argon to shield the start area and provide an escape route for entrapped gas when the weld overlaps the start area.

Both the head and Y-ring subassemblies are welded from the inside in the downhand position on a tilted rotary positioner, as shown in Fig. 3. The head is held in shape for welding to the Y-ring by a contoured vacuum platen (Fig. 4). A forged connecting ring is welded

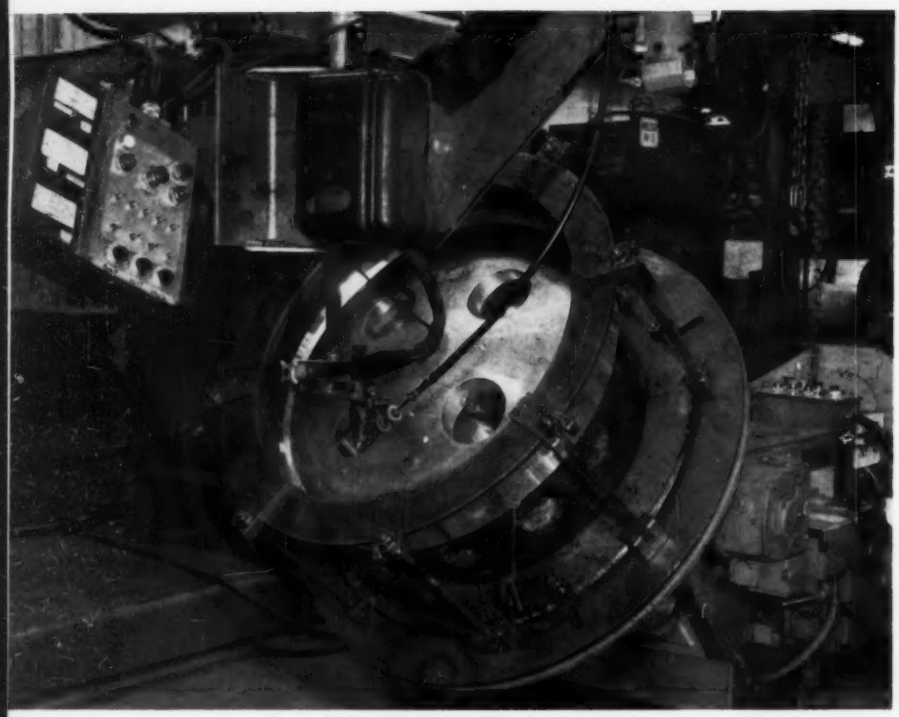


Fig. 3 — Complete Head-to-Y-Ring Assembly, Ready to Weld. Note conveniently located operator controls and meters, large radius of curvature in wire delivery tube

to the forward-head Y-ring and a flanged skirt (for support during heat treatment) is welded to the aft-head Y-ring (Fig. 5). This support flange and the weld is removed after heat treatment of the tank assembly.

Two of the shell-to-forging subassemblies are then circumferentially welded. The aft-head subassembly is welded to one of these (Fig. 6) and the two sections are then welded to form the complete tank (shown in Fig. 1). There are 11 110-in. circumferential welds, two 93-in. circumferential head welds, and about 100-in. of longitudinal welds in the completed tank.

Expanding mandrels, shown in Fig. 7, are used to insure matched fitup for all circumferential welds. Initially, stainless steel backup shoes were used with these mandrels because shoes made of copper smeared the aluminum parts during mandrel expansion. However, severe warpage of the stainless shoes created a replacement problem, and the high-pressure contact of the shoes with the part caused the weld underbead to stick to them. When the part was removed, small slivers of aluminum were pulled out of the underbead. It was found that copper shoes plated with chromium provide an excellent parting surface and also prevent copper pickup. In addition, they are easily cleaned and do not warp.

Processing Specifications Are Exacting

All parts are meticulously cleaned prior to welding. Rolled sheet is vapor degreased and then etched or chem-milled. Subsequent cleaning is limited to vapor degreasing, solvent degreasing, or mechanical cleaning. The etching process consists of deoxidizing in an alkaline solution, rinsing in hot water, acid dipping for smut removal, rinsing in hot water, and drying in hot air. The chem-mill process uses an alkaline etch with similar rinsing cycles. No etching is allowed on as-welded parts because the weld zone is susceptible to intergranular attack.

Because all parts are not welded immediately after the etching process, they are wrapped, and then stored on specially designed dollies. Welding preparations consist of the following: Wipe parts with solvent; buff with a rotary, stainless-steel wire brush; install on weld positioner; scrape all abutting surfaces to expose a fresh metallic surface; chamfer all corners; polish with stainless steel wool. After the weld fixture is closed, a setup mechanic corrects any minor mismatch and requests inspection approval for welding.

Table I – Weld Settings for a Longitudinal Weld, Forward Center Shell, Bomarc Ramjet

Material: 0.160-in. 2219 alloy (0 to T 6)	
Joint type: square butt	
Bevel angle: none	
Root opening: none	
Travel speed: 14* and 12† in. per min.	
Weld current: 150* and 125† amp.	
Arc voltage: 12* and 14† v.	
Wire feed: 5 to 35* and 20 to 60† in. per min.	
Wire material: 0.062-in. 2319 alloy	
Electrode: W-2% Th (120°)‡	
Inert gas: He (75 cu.ft. per hr. at nozzle)	
Backup: chromium-plated copper	
Welding head: DCSP	

*First pass.
†Second pass.
‡First pass: 3/32-in. diam., 60° tip; Second pass: 1/8-in. diam., 120° tip.

Welding Procedure

Welds are made with TIG-DCSP* equipment (Fig. 8) for the best combination of mechanical properties and weld quality. Only weld settings certified by Boeing and the Air Force are used on production welds. All joints and tools have individual certified weld settings, developed by the master welder on simulated parts. Specimens cut from these welds are heat treated, metallographically examined, and tested for mechanical properties. Table I shows a typical certified weld setting.

We also tried a titanium backup bar (low heat conductivity) for single-pass welds. The experimental settings – using high welding current (275 amp.) and fast wire-feed rates (68 in. per min.) – produced welds with slightly improved ductility. Single-pass welds are extremely sensitive to minor fluctuations in current, voltage, travel speed, and wire-feed rates. With single-pass welds, we could not obtain consistent, high quality on 0.25-in. 2219 plate without using a backup bar of low heat conductivity.

To reduce defects, care must be taken in preparing and making the original weld. As an example, a preset tail-out sequence is used in which weld current and wire feed are reduced while voltage is simultaneously increased. This produces a long tapered tail-out weld bead with minimum cracking tendency in the crater. A crack which can be identified with the original crater sometimes occurs after heat treatment, though no defect is revealed in the original x-ray of the weld. Special attention to the tail-out and the use of automatic downslope timers have minimized this problem.

*Inert gas, tungsten arc; direct current, straight polarity.

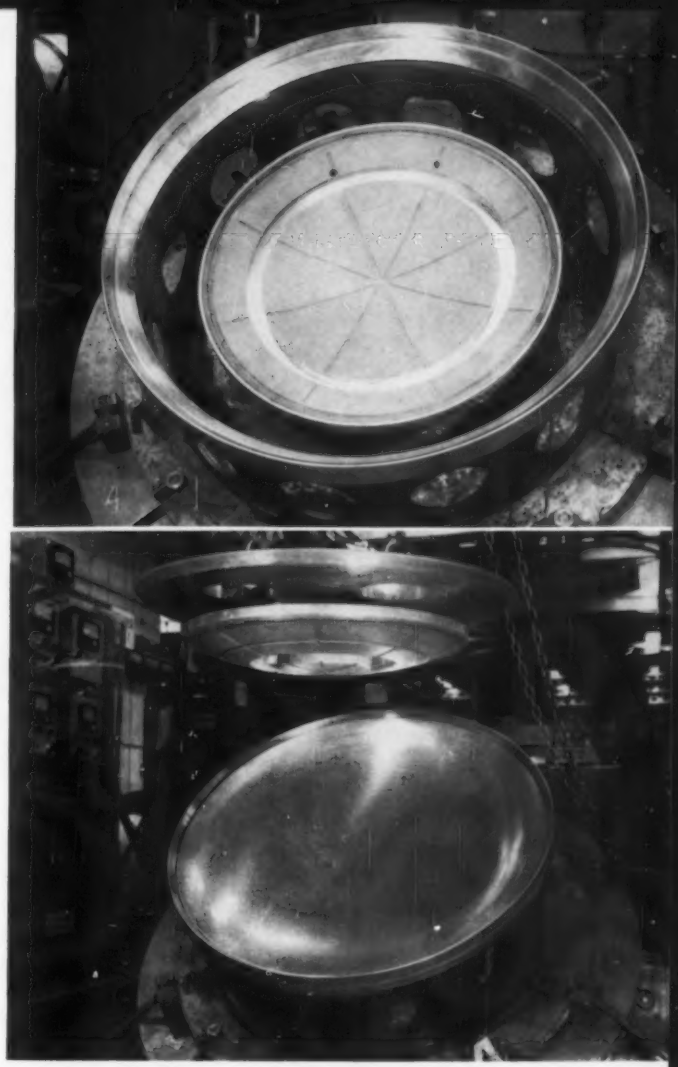


Fig. 4 – (Top) Welding Fixture for Joining Y-Ring to Tank Head on a Rotating Tilt Positioner. Note chromium-plated backup ring and external vacuum holddown platen. (Bottom) Tank head in position on external vacuum platen. Internal holddown platen is ready to lower into place after Y-ring is installed

Early in the Bomarc program, an increase in the defect rate was traced to use of impure helium. Thereafter, each bottle of helium was tested on a trial weld and graded as acceptable for welding of aluminum. Gas purity is now guaranteed by the vendor and this weld test is no longer required. Only helium is used with TIG-DCSP welding on 2219 because of poor weld-bead geometry and low radiographic quality of the welds made with other shielding gases.

Welding processes other than TIG-DCSP

Fig. 5 – Fitting and Heat Treat Support Flange on Ramjet Tank. Hole is for a "bonded-on" pressure tap; inked-on numbers are used in x-ray film indexing

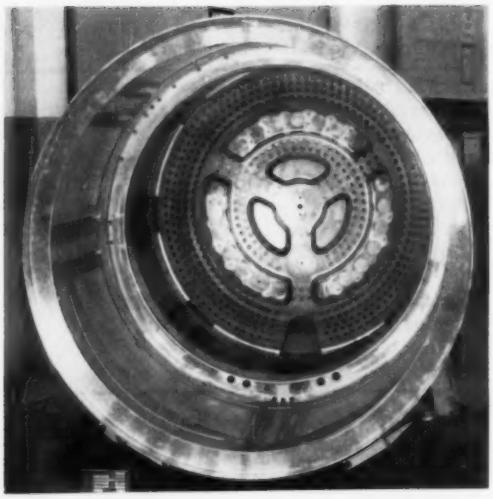


Fig. 6 – Aft-Head Subassembly Is Circumferentially Welded to a "Shell-to-Forging" Subassembly. Bladder attach ring, ramjet attach frame, and channeled fuel colander are shown. Note chem-milled areas

have been investigated. Welds made with balanced-wave, AC-TIG equipment have not shown any quality advantage and produce somewhat lower mechanical properties. Wider heat-affected zones and larger weld nuggets are also obtained.

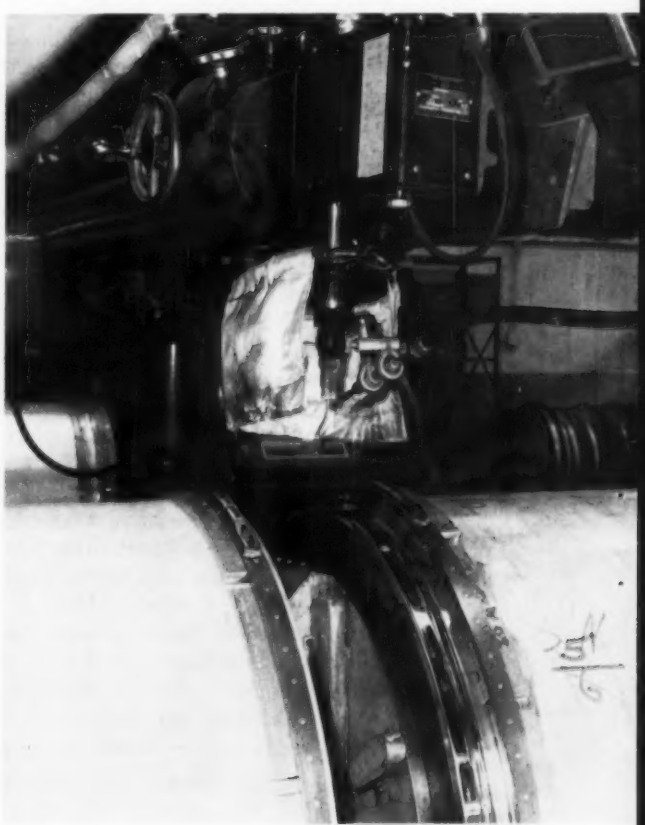
Welds made with the MIG* process could not meet quality or ductility requirements. However, the short-arc stabilized (SAS-MIG) process is promising. Radiographic quality standards can be met and as-welded ultimate and yield strengths exceed those of corresponding TIG welds. Elongation and notched ultimate strength are slightly lower than on welds produced by TIG-DCSP.

After the tank components are welded, the top bead and underbeads are shaved almost flush with the surface to meet aerodynamic requirements. Shaving removes surface and near-surface defects commonly associated with the normal oxide layer of the weld. A dye-penetrant and visual inspection is made for cracks, exposed porosity, and undercutting. Defects found by these methods are removed and repaired.

Requirements for Weld Repair

All welds must meet Bomarc weld quality specifications, which are equivalent to ABMA (Army Ballistic Missile Agency) Class II requirements. The present defect rate averages

Fig. 7 – Expanding Mandrel with Chromium-Plated Backup Shoes Insure Matched Fitup on All Circumferential Welds



*Consumable electrode, inert-gas shielded.

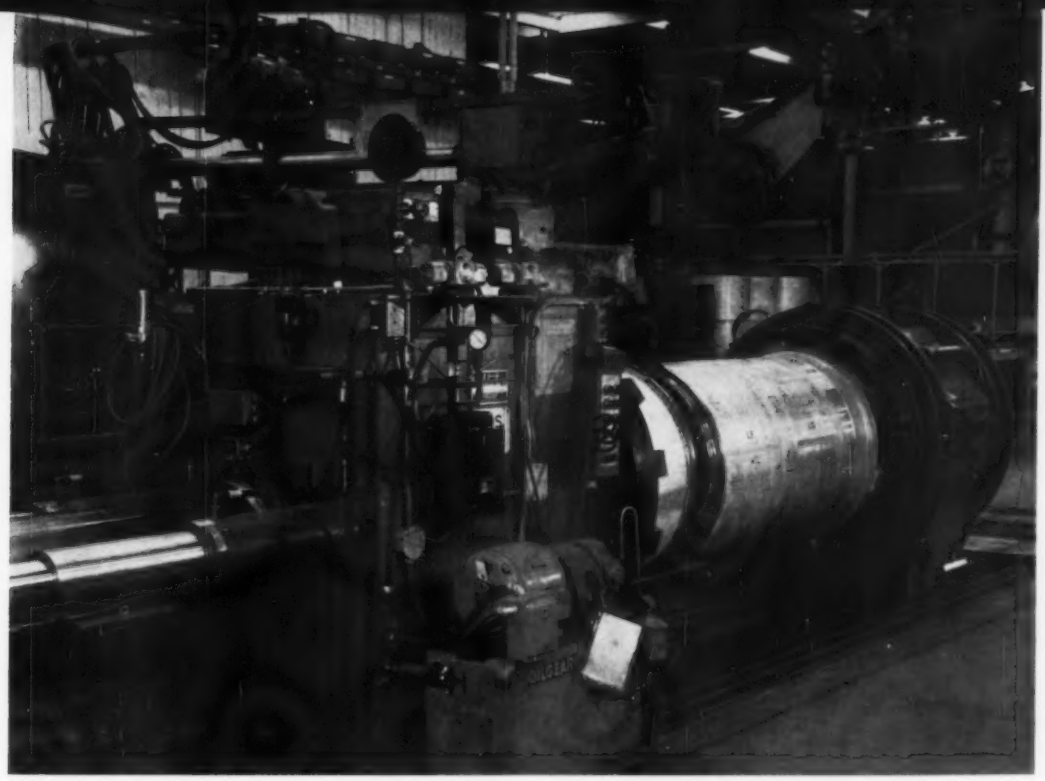


Fig. 8 – Tank Subassembly Is Ready for TIG-DCSP Welding in Expanding Mandrel Headstock and Tailstock

8 in. of defects per 1000 in. of original weld. Porosity is the most common defect, and inclusions rank second. The incidence of cracking is very low and can usually be traced to some deviation from established practice.

To locate and repair a defect, we index the x-ray film which shows the defect, and mark its position on the part directly from the film. A mechanic experienced in locating defects determines whether the repair is to be made on the interior or exterior of the tank. After the defect is exposed, it is removed with a small radial milling cutter. Complete removal is verified by inspection with penetrant or x-ray. The cutout area is then shaped to the optimum configuration for easy manual repair welding. Minimum metal removal is mandatory to reduce the extent of the relatively brittle repair weld and to minimize distortion. For good weld quality the cut must be clean and have a surface finish equivalent to 32 rms.

Repair welds are made with manual TIG (balanced wave, high-frequency stabilized) welding equipment employing alternating current. No preheating is required for the relatively thin material used in the Bomarc tanks.

Tank Is Heat Treated

After final weld acceptance, the tank is fitted with external holding fixtures to provide vertical support during solution heat treating and immersion quenching. The fixture clamps to a specially flanged skirt on the upper end of the tank. Tooling must allow for expansion and contraction and provide adequate support (about 75% of tank weight) while the tank is in a weakened condition at 1000° F. Within 10 sec. after it is removed from the bottom-loaded vertical furnace, the tank is submerged in 150° F. water. The hotter quench temperature minimizes the distortion that is usually encountered in water at 60° F. Artificial aging to the T 61E46* temper is accomplished at 350° F. for 12 hr.

The mechanical properties of welds in the T 6E46 condition are the highest of any obtainable with this alloy (65,000 psi. tensile, 47,000 psi. yield, and 12% elongation). The higher quenching temperature (T 61E46) produces slightly lower strength. Tensile strength is reduced by 5,000 psi. and yield strength by 3,000 psi.; elongation is improved by about 3%.

A final inspection of all welds with dye penetrant is made to insure that no cracking occurred during heat treatment.

*This is a Boeing designation for a modification of the T 6E46 temper. The "1" indicates a 150° F. rather than 60° F. quench. E46 indicates a nonstandard heat treatment developed by Alcoa. Treatment should be used with care, since susceptibility to stress-corrosion cracking may become a problem.

Malleable Irons . . . Versatile Engineering Materials

*HANS J. HEINE**

During the last decade, the foundry industry has made significant progress in advancing the technology of malleable irons. More is known about machinability – one of the greatest assets of these engineering materials – and recent studies confirm their excellent stress-rupture properties to at least 800° F. (Q-general, G17k; CI-s)

MALLEABLE IRON IS OFTEN REFERRED TO as though it were a single product, all of one class or grade, when, in fact, three classes and numerous grades with wide ranges of mechanical and engineering properties are regularly produced. Of the three classes of malleable iron, two are of principal importance. One is ferritic malleable, which consists largely of ferrite interspersed with nodules of temper carbon. Produced in two grades, ferritic malleable leads the field in production volume.

The second major class includes the pearlitic malleables. These contain some carbon in the combined form because of special heat treatment, alloying or both. A third class, alloyed malleable, is completely graphitized. It has a ferritic matrix and owes its higher strength to alloy content.

The range of applications for malleable irons is a wide one. In size, it extends from small chain links, weighing a fraction of an ounce, to giant ingot molds weighing 3960 lb., with some sections more than 7 in. thick. In design, it comprises both the simple shapes of rings, washers and blocks, and complex structures such as gear cases. In utility, applications extend from ornamental iron railings – with fine finish and excellent detail – to highly stressed automotive universal joint yokes and flanges of pearlitic malleable iron.

Important Properties

The *Metal Progress* Data Sheet on p. 96-B presents minimum strengths listed in A.S.T.M. specifications along with other important engineering properties of malleable irons. It can be seen that these casting materials possess tensile strengths similar to those of many steels. In addition, the yield strengths of malleable irons are 65 to 75% of their tensile strengths. A high ratio of fatigue strength to tensile strength is also a characteristic of malleable irons; it ranges from 0.4 to 0.6. And the damping capacity of malleable iron – ability to absorb impact forces and dissipate the energy as heat rather than vibration – is about three times that of steel and twice that of nodular iron.

Impact Resistance – The two standard impact tests – Charpy and Izod – give identical values (14 to 17 ft-lb.) for malleable when V-notched bars are tested. These values are slightly superior to those of nodular iron (10 to 15 ft-lb.) but not as high as those of steel (11 to 34 ft-lb.). Unnotched malleable specimens, as expected, show much higher impact strengths. A machined test bar, smaller than that used for Charpy and Izod tests but without a notch, is capable of withstanding two to three times the loads applied in the Charpy tests. The table below shows results of a tensile-impact test, using the smaller test bar and a pendulum-type impact machine according to A.S.T.M. specifications:

TENSILE STRENGTH	ELONGATION IN 2 IN.	TENSILE-IMPACT STRENGTH	IMPACT ELONGATION
54,300 psi.	21%	43.5 ft-lb.	11%
57,200	14.5	25	6

*Technical Director, Malleable Founders Society, Cleveland.

Corrosion Resistance – The corrosion resistance of malleable irons in common weathering conditions, water and salt water is better than that of medium carbon steel and wrought iron. This is due to a shallow (0.008 to 0.010 in.) skin of ferrite on malleable castings which is highly resistant to most ordinary atmospheric conditions and salt water. Even after machining, the ferrite matrix still provides good corrosion resistance. Copper, added alone and in combination with molybdenum, improves resistance to atmospheric corrosion. Copper additions, in particular, improve resistance to sulfurous atmospheres, and in alloyed malleables, copper contents of up to 2.00% also increase resistance to corrosion by flue gases.

Where Malleable Irons Are Used

As the Data Sheet shows, ferritic malleable irons, grades 32510 and 35018, have good strength, a high ratio of yield to tensile strength, and excellent ductility. Because of their good castability, toughness, fatigue strength, and excellent machinability, the ferritic grades are desirable for many automotive, agricultural implement, railroad, and general industry applications. A new nitriding process (see "A New Nitriding Process From Germany", *Metal Progress*, July 1961, p. 77) shows definite possibilities for application to ferritic malleable castings. It can be used to overcome the inherent softness of the material, opening the door for new uses where wear resistance is necessary.

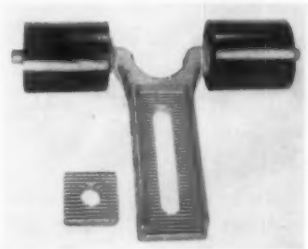
Pearlitic malleables are primarily employed for components requiring wear resistance, high hardness, hardenability, and high strength. The modulus of elasticity is high (28×10^6 psi.) and castability, toughness, and machinability are retained.

Case Histories

A good example of the application of ferritic malleable is its use in handles for air-powered impact wrenches. Here the primary need is for fatigue strength because the handle must withstand repeated impact loads as it cuts metal, breaks welds, splits nuts, shears bolts and punches out pins. Malleable was chosen on the basis of its high yield strength and favorable ductility which eliminated breakage near the area of impact on the casting.

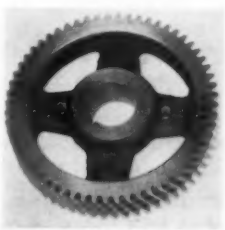
Where machinability and wear resistance are necessary, many parts are made of pearlitic malleable. Camshaft and idler gears, used in V-6 and V-12 truck engines, are typical appli-

Ring Gear of Pearlitic Malleable

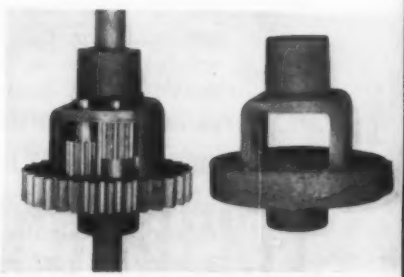


Keel Roller for a Boat Trailer

Pipe Vise of Ferritic Malleable



Pearlitic Malleable Gear



Pearlitic Malleable Drive Gears

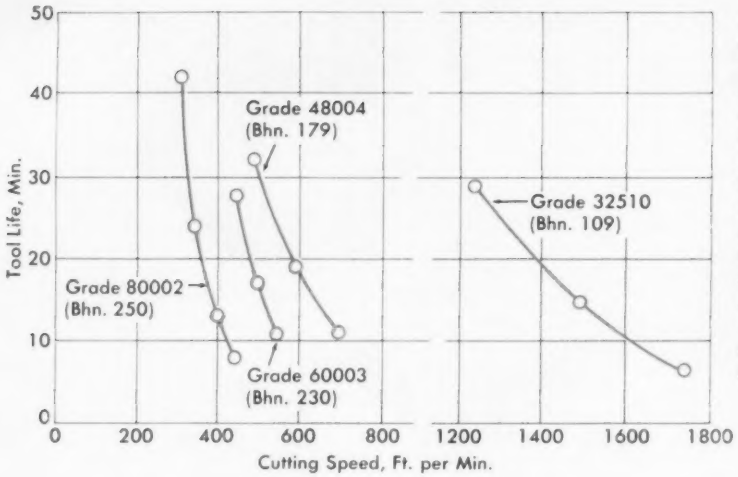


Fig. 1 – Curves Relating Cutting Speed (for Underskin Finish Cuts) With Tool Life Are Based on Extensive Data Gathered During Machinability Study Made by Malleable Founders Society. To obtain data presented here, each sample was machined with a C2 carbide tool; test was ended when 0.015-in. wearland developed. Tool geometry: back rake, 0°; side rake, 5°; side-cutting edge angle, 15°; end-cutting edge angle, 15°; relief, 5°; nose radius, 3/64 in.; feed, 0.007 in. per rev.; depth of cut, 0.010 in.; cutting fluid, soluble oil (1 part oil, 20 parts water)

cations for which pearlitic malleable is used because of its excellent machinability and wear resistance. In the original material from which these parts were made, machinability proved inadequate and the tolerances of the teeth were difficult to maintain. Two grades of pearlitic malleable (60003 and 80002) were tried and both improved machining characteristics. Oil-quenched 80002 was chosen because it proved the most wear resistant of the two. The idler gear shaft was converted from a forging at the same time to take advantage of a 14% cost reduction.

There are numerous applications requiring wear resistance which have in the past precluded the use of ferritic malleable iron. Studies by the Malleable Founders Society reveal that the new nitriding process previously mentioned can increase wear resistance by a factor of 10 and fatigue strength by almost 30%. This should expand use of ferritic malleable iron in many applications.

When requirements call for high strength along with wear resistance, pearlitic malleables should be specified since they are inherently stronger and more wear resistant. In addition, pearlitic irons show excellent response to localized hardening; they have hardenability characteristics similar to those of A.I.S.I. 1340 and 4045 steel. A hardness of Rockwell C-50 is readily obtainable on thickness of 1 in. or less.

High-Temperature Properties

An investigation of high-temperature characteristics of malleable castings has revealed excellent stress-rupture properties up to at least 800° F. This is particularly true of the pearlitic malleables which may be satisfactory in some applications at temperatures as high as 1200° F. (For further information see "Properties of Malleable Iron at Elevated Temperatures", *Metal Progress*, March 1960, p. 102.) The study points out one significant fact: The strength of malleable iron decreases at a uniform, gradual rate with increase in temperature because no graphitization takes place; there is no abrupt decrease in rupture strength. Additional tests on pearlitic malleable irons containing manganese and molybdenum indicate a considerably higher rupture strength at elevated temperatures than that found in unalloyed irons.

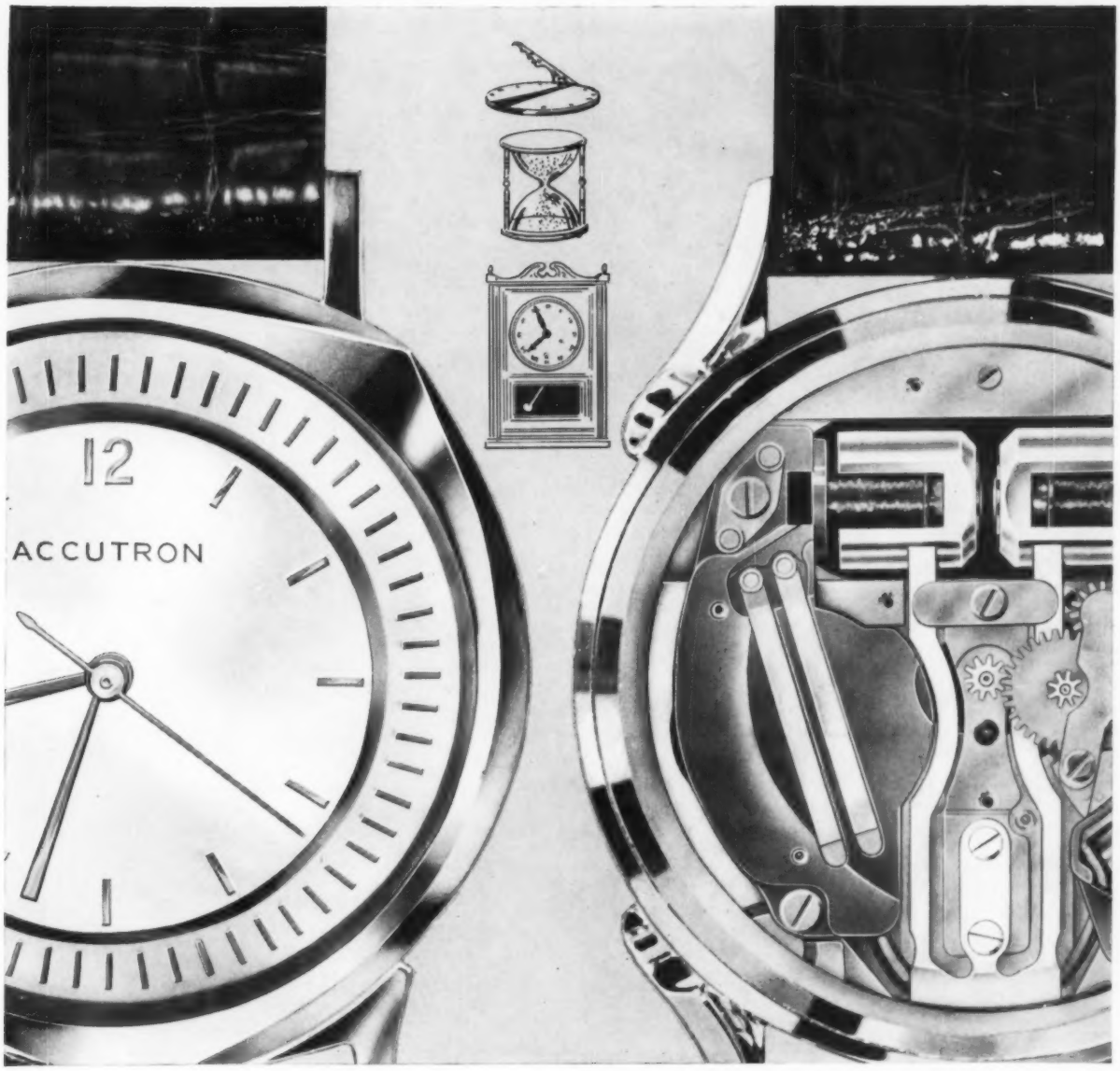
New Data on Machinability

One of the principal advantages of malleable iron is its excellent machinability. This has been confirmed by a study made recently by the Malleable Founders Society. Curves relating tool life to cutting speed, surface finish, and cutting fluid have been obtained for both ferritic and pearlitic malleable irons. Figure 1 presents typical data on turning four grades of malleable iron for underskin finish cuts.

In addition, the study has brought out these conclusions:

- Cutting speed can be increased 10 to 50% in certain turning operations when a soluble-oil cutting fluid is employed as opposed to dry cutting.
- Negative rake tools are superior to positive rake tools for coarse underskin cuts at high feed rates.

At high feed rates, a tool nose radius of 1/16 in. (compared with a 3/64-in. radius) greatly improves surface finish.



How Nickel helps make timekeeping history

Electronic tuning fork made of a Nickel alloy represents the most basic advance in personal timekeeping in 300 years

A watch you don't need to wind. A watch without mainspring, balance wheel, or hairspring. A watch that doesn't gain or lose more than 2 seconds out of every 86,400!

The secret of the fantastic timekeeping accuracy of Accutron* is a precision tuning fork that vibrates more than 31 million times every twenty-four hours—day after day, week after week, month after month...powered by a button-size battery.

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That's why electronic engineers chose Ni-Span-C† alloy (42% Nickel) for the heart of this space-age marvel. This high Nickel alloy maintains the fork's vital stiffness at temperatures from 0° to 150° F...fights off damaging corrosion and oxidation.

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Circle 1922 on Page 48-B

Properties and Applications of Malleable Iron Castings

Designation	Mechanical Properties				Other Properties	Typical Applications
	Tensile Strength*	Yield Strength*	Elongation in 2 In.*	Brinell Hardness		
Ferritic						
35018	53,000 psi.	35,000 psi.	18%	110-156	Modulus of elasticity in tension: 25×10^6 psi.; fatigue strength: 40 to 60% of tensile strength; damping capacity (energy lost in one vibration cycle): 4.2% at 30,000 psi.; compressive strength: 200,000 psi.; torsional strength: equals tensile strength; shear strength: 80 to 90% of tensile strength	Iron grillework, railroad car hardware, hand tools, high-pressure parts, hardware for oil industry.
32510	50,000	32,500	10	110-156		Gear cases and housings, chain links, auto hinges, brackets, mounting pads, brake shoes, wheel hubs.
Pearlitic						
45010	65,000	45,000	10	163-207	Modulus of elasticity in tension: 26×10^6 to 28×10^6 psi.; fatigue strength: 40 to 60% of tensile strength; damping capacity (energy lost in one vibration cycle): 5.3% at 35,000 psi.; compressive strength: 200,000 psi.; torsional strength: equals tensile strength; shear strength: 70 to 80% of tensile strength	C-clamps, diesel engine brackets, levers, transmission cases, artillery shells, gears, farm implement parts.
45007	68,000	45,000	7	163-217		
48004	70,000	48,000	4	163-228		
50007	75,000	50,000	7	179-228		
53004	80,000	60,000	4	197-241		
60003	80,000	60,000	3	197-255		Pistons for diesel engines, differential axle cases, rocker arms, clutch hubs, transmission gears, universal joint yokes, crankshafts, idler gears and shafts.
80002	100,000	80,000	2	241-269		

* ASTM minimum

Recommended Cutting Conditions for Turning Four Grades of Malleable Iron

Grade	Type of Cut*	Cutting Speed, Ft. per Min.	Feed, In. per Rev.	Depth of Cut, In.	Tool Life, Min.
32510 (Bhn. 109)	Roughing skin	450	0.015	0.100	25
		400	0.030	0.100	22
	Coarse underskin	750	0.015	0.060	29
		550	0.030	0.060	30
	Finish	1500	0.003	0.010	32
		1300	0.007	0.010	28
48004 (Bhn. 179)	Roughing skin	200	0.015	0.100	34
		150	0.030	0.100	29
	Coarse underskin	300	0.015	0.060	35
		225	0.030	0.060	35
	Finish	650	0.003	0.010	30
		500	0.007	0.010	32
60003 (Bhn. 230)	Roughing skin	150	0.015	0.100	35
		125	0.030	0.100	27
	Coarse underskin	225	0.015	0.060	30
		175	0.030	0.060	28
	Finish	500	0.003	0.010	32
		450	0.007	0.010	28
80002 (Bhn. 250)	Roughing skin	150	0.015	0.100	35
		100	0.030	0.100	35
	Coarse underskin	150	0.015	0.060	45
		100	0.030	0.060	40
	Finish	400	0.003	0.010	35
		300	0.007	0.010	42

*Tool geometry for roughing skin and coarse underskin cuts: −5° BR, 15° SCEA; −5° SR, 15° ECEA; 5° relief. Tool geometry for finish cuts: 0° BR, 15° SCEA; 5° SR, 15° ECEA; 5° relief.

All tests were made under the direction of the Machining Subcommittee of the Malleable Founders Society, Cleveland. Grade C-2 cutting tools were used with soluble-oil cutting fluid. Tests were discontinued at a uniform wearland of 0.015 in.

A Metal for Service at Both Cryogenic and Ultrahigh Temperatures

*By H. R. OGDEN and I. PERLMUTTER**

Tantalum alloys may be useful for parts requiring a combination of toughness at cryogenic temperatures with strength at high temperature. (Q-general, 2-62, 2-63; Ta)

MANY METALS ARE SUITABLE for use at cryogenic temperatures and others can be employed at very high temperatures. Now under development for high-temperature applications is a metal which also has excellent cryogenic properties. This metal is tantalum.

Tantalum is well known for its excellent corrosion resistance and electronic properties. Its high density, low strength, and restricted availability were the chief reasons why it was originally bypassed in favor of the more plentiful and less dense columbium and molybdenum.

Although early work† had shown that tantalum was somewhat weaker at high temperatures than its high melting point suggested, certain inherent properties indicated that it should have great potential as a base for the development of high-temperature alloys. Of particular importance are its excellent low-temperature ductility and its high tolerance for interstitials. These advantages, coupled with its high melting point and potential high-temperature strength (based on the principles derived by Dorn‡ relating activation energy for creep to that of self-diffusion), appeared sufficiently attractive to the U.S. Air Force to initiate development programs on tantalum.

The Unalloyed Metal

Tantalum, along with columbium and vanadium, are the Group V-A transition elements, and like the Group VI-A elements (tungsten, molybdenum, and chromium), they have the body-centered cubic crystal structure. However, in many respects, the Group V-A elements differ from the Group VI-A elements.

In general, the Group V-A metals have low moduli of elasticity, high solubility for the interstitial elements, and good ductility at low temperatures. The Group VI-A metals, on the other hand, have very high moduli of elasticity, very low solubility for the interstitial elements, and undergo a ductile-to-brittle transition at room temperature or above. The Group V-A metals retain their ductility in the recrystallized condition, whereas the Group VI-A metals are ductile to lower temperatures in the wrought or fibered condition as compared to the recrystallized condition.

The low-temperature ductilities (and tensile strengths) of the four important refractory metals are shown in Fig. 1. Of these refractory metals, only tantalum does not undergo

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†"Temperature Dependence of the Tensile Properties of Tantalum," by J. W. Pugh, *Transaction* A.S.M., Vol. 48, 1956, p. 677-688.

‡"The Spectrum of Activation Energies for Creep," by J. E. Dorn, Creep and Recovery, A.S.M., Cleveland, Ohio, 1957, p. 255-283.

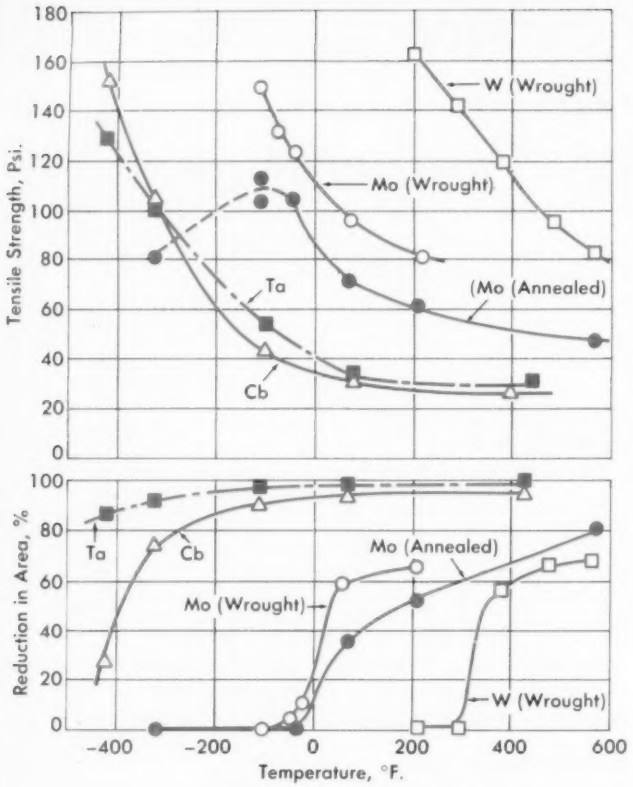


Fig. 1 – Strength and Ductility of Refractory Metals at Low Temperatures

a ductile-brittle transition at subzero temperatures. Barrett* has reported ductility in tantalum at 4.2° K. (−451.8° F.). Also, it is shown that the tensile strength of the refractory metals increases very rapidly with decreasing temperature at low temperatures. This phenomenon has been associated with body-centered cubic metals and is considered to be indicative of the ductile-to-brittle transition. However, it should be noted that of the refractory metals, only tantalum retains ductility while, at the same time, exhibiting this rapid increase in tensile strength.

*"Metallurgy at Low Temperatures," by C. S. Barrett, *Transaction* A.S.M., Vol. 49, 1957, p. 53-117.

Tantalum Alloys

Studies on the development of columbium-base alloys have shown that the improvement in strength obtained through alloying has been made at a sacrifice in ductility at low temperatures. Perhaps this resulted from using Group VI-A elements as alloying additions so that the columbium alloys take on some of the characteristics of the Group VI-A elements.

In developing tantalum-base alloys, one of the approaches has been to improve high-temperature strength without sacrificing low-temperature ductility by alloying only with Group V-A elements. This approach has resulted in a family of alloys which have strength levels comparable to molybdenum and columbium alloys, while maintaining the excellent cryogenic properties of unalloyed tantalum. An added feature in this family of alloys is the decrease in density which is obtained when columbium and vanadium are added. The 30 Cb, 7.5 V tantalum alloy has a measured density of 0.426 lb. per cu.in. compared to 0.600 lb. per cu.in. for tantalum.

Ductility Extends Over Broad Range

Typical properties of three tantalum-columbium-vanadium alloys and high-purity tantalum over the range of −320° F. to 3000° F. are given in Table I. It should be noted that duc-

Table I – Properties of Annealed Tantalum Alloys at Cryogenic and Ultrahigh Temperatures

Test Temp., °F.	Tantalum			30 Cb, 5 V Tantalum			30 Cb, 7.5 V Tantalum			30 Cb, 10 V Tantalum		
	Yield 1000 Psi.	Ultimate 1000 Psi.	Elongation, %	Yield 1000 Psi.	Ultimate 1000 Psi.	Elongation, %	Yield 1000 Psi.	Ultimate 1000 Psi.	Elongation, %	Yield 1000 Psi.	Ultimate 1000 Psi.	Elongation, %
−320	96	101	8	158	168	26	—	—	—	189	217	21
75	23	30	36	78	96	22	125	139	27	127	148	21
2190	—	11	45	40	45	52	48	61	35	35	64	18
2400	8	10	32	20	28	48	—	—	—	30	42	76
2600	—	5	66	18	22	86	22	36	76	19	27	104
2730	—	—	—	14	16	111	—	—	—	12	20	114
2900	—	3	69	9	13	107	—	—	—	—	—	—
3000	—	3	82	5	9	85	6	10	99	—	9	124

tility remains high throughout this range despite the fact that tensile strength increases rapidly at subzero temperatures. A comparison of the strength-to-density ratio (above 1800° F.) of the 30 Cb, 10 V tantalum alloy with those of molybdenum and columbium alloys and unalloyed tungsten is shown in Fig. 2. It can be seen that as the temperature is increased the tantalum alloys appear to be stronger than the columbium and molybdenum alloys, but not as strong as tungsten.

It should be recognized that tungsten, because of its very high melting point, will be the material for use at the ultrahigh temperatures. However, tantalum alloys will probably be employed over a broader temperature range than molybdenum and columbium alloys. When a constructional material is required with good cryogenic properties, as well as good high-temperature strength, tantalum and tantalum alloys are the only materials suitable.

Another important advantage of tantalum alloys over other refractory alloys is their good ductility in the recrystallized condition. In fact, the tantalum-columbium-vanadium family of alloys can be cold worked extensively after the initial breakdown fabrication. Because of their excellent ductility in the recrystallized condition, these tantalum alloys are not embrittled during welding. Bend ductilities of less than 2T have been obtained in welded tantalum-columbium-vanadium alloys.

Tantalum As a Cryogenic Material

Refractory metals have not been considered for cryogenic applications since there are many other metals which have excellent strength-ductility combinations at low temperatures. However, when a combination of toughness at low temperature with strength at high temperature is required, tantalum alloys may be advantageous. A comparison of the properties of tantalum alloys with high-strength cryogenic materials, such as titanium alloys and A-286, is shown in Fig. 3.

The development of tantalum-base alloys is in its early stages, and new alloys can be expected in the future. Because of the promise shown in laboratory work, the Air Force has initiated a program to scale up the more promising compositions from alloy development programs. One of the compositions included in the program is 30 Cb, 7.5 V tantalum alloy. A more complete metallurgical evaluation will also be made of these alloys.

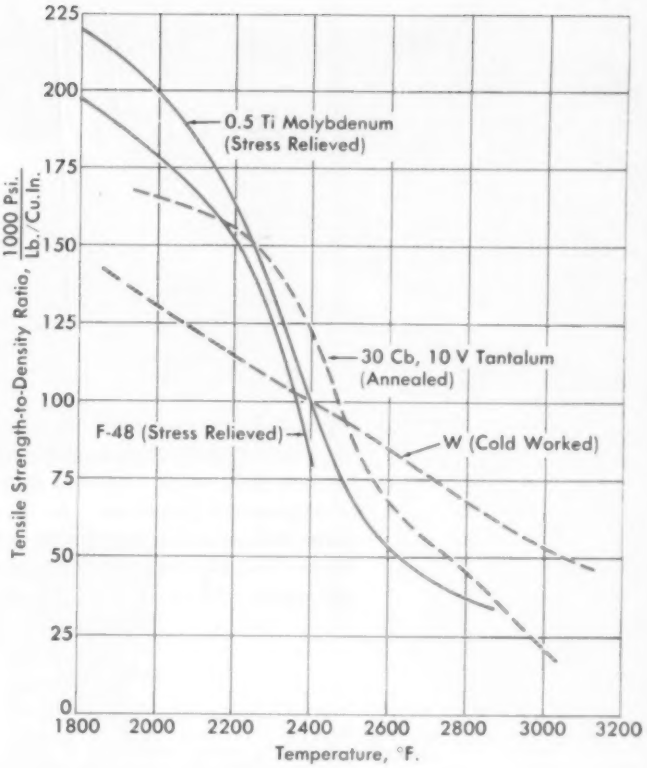
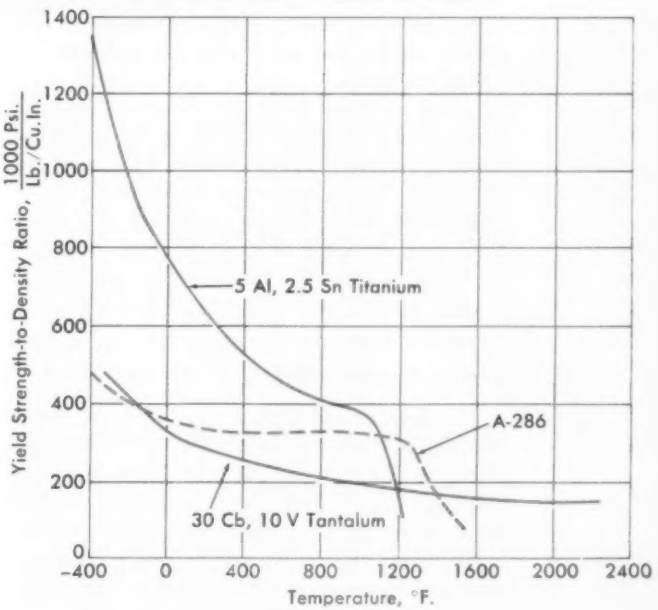


Fig. 2 – How Strength-to-Density Ratio of Tantalum Alloy Compares With Other High-Temperature Alloys

Fig. 3 – How Strength-to-Density Ratio of Tantalum Alloy Compares With Other High-Strength Cryogenic Alloys



Stainless Steels for High-Strength Welded Structures and Components

STAFF REPORT

Stainless steels, including the more recent precipitation-hardening grades, have become important engineering materials for welded structures because they resist corrosion in many environments and permit a wide choice of mechanical properties. As in any welding operation, particular attention must be given to metallurgical structure. Proper heat treatment after welding will insure excellent corrosion resistance and strong, ductile welds. (Q-general, K-general, R-general; SS)

STAINLESS STEELS HAVE ENJOYED a long history of successful applications in welded, high-strength structures. Spot welded structures for the railroad and transportation industries, tanks for cryogenic and high-temperature service, jet engine components, chemical-plant equipment and, most recently, aircraft and missile structures are only a few of the applications where welded stainless steels have proven to be the most effective solution to design problems.

Listed in Table I are the compositions and base-metal properties of some of the stainless steels commonly used in welded, high-strength structures. These important engineering materials permit designers and fabricators to choose from a broad range of strength levels between the relatively low-strength austenitic and ferritic grades to the strong martensitic and semi-austenitic compositions.

Ferritic Stainless Steel

The ferritic stainless steels, such as Type 405, 430 and 446, may not be considered high-strength steels in relation to other stronger stainless grades, but they do possess higher strength levels than many nonferrous alloys.

These grades are essentially ferritic in structure and do not normally respond to heat treatment to increase their strength. When heated to and cooled rapidly from temperatures greater than 1700° F. (as in welding), some intergranular carbide precipitation or sensitization occurs at the weld-base metal interface as well as within the fusion zone. When such conditions occur, there is a significant decrease in corrosion resistance at these locations. Such heating and cooling also promotes the formation of grain-boundary martensite as well as grain growth. Both of these lead to a drop in weld ductility.

These detrimental effects can be minimized by heating the weld within the range of 1200 to 1500° F., followed by cooling in air. Type 430, for example, when welded and then heated to 1400° F. for 5 min., is not susceptible to intergranular corrosion. The treatment at 1400° F. decreases the strength somewhat (to about 45,000 psi. yield, 71,000 psi tensile) compared to that of the as-welded material, but ductility is improved.

Improvements in weldability and in ductility of ferritic stainless steel welds can be obtained by the addition of small amounts of titanium. Such additions decrease the amount of intergranular martensite and increase the temperature at which sensitization occurs. They do not, however, eliminate the need for postweld

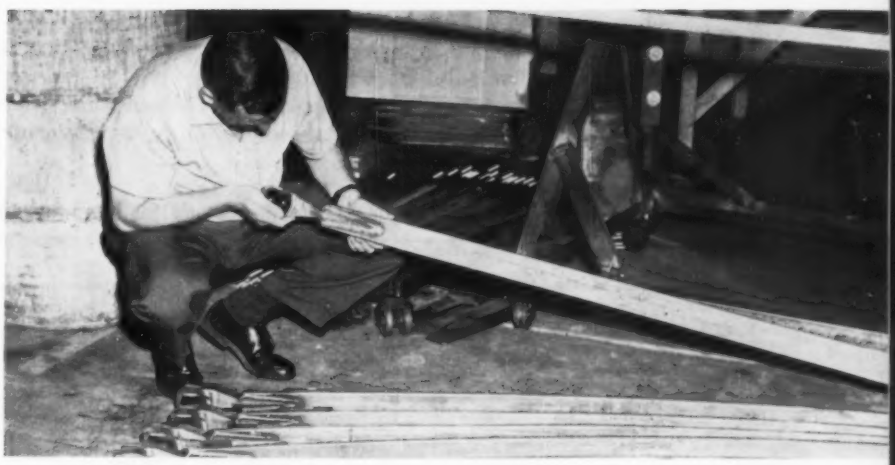


Fig. 1 – Tailhook of 17-4 PH Carried by F-106 Will Stop the 33,250-Lb. Fighter by Engaging an Arresting Cable During Landing Emergency. Basic assembly consists of a forged hook welded to a spring shank. Heat treatment is done after welding

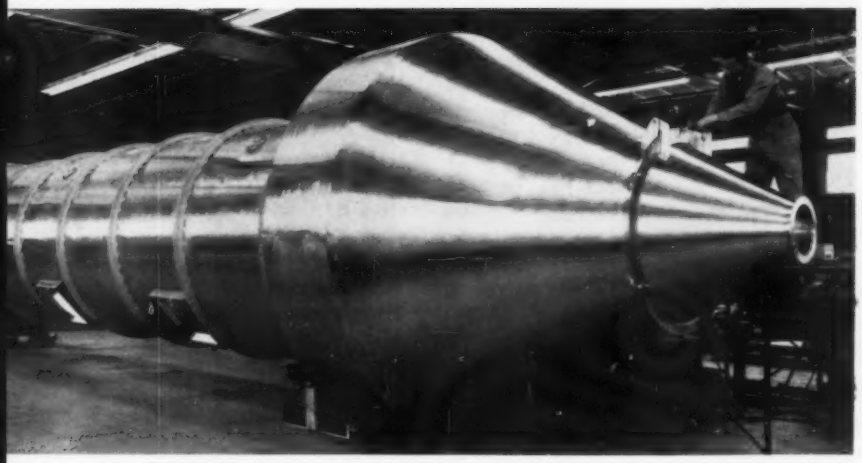


Fig. 2 – Spray Dryer of Welded Type 304 Stainless Steel. Structures fabricated of austenitic stainless should be heated after being welded to dissolve chromium carbide particles and thus minimize the effects of sensitization

heating to 1200 to 1500° F. when maximum corrosion resistance is required.

Austenitic Stainless Steel

Among the best known and most widely used of the stainless steels are the so-called 18-8 or austenitic grades. These include Type 301, 302, 304, 304 L as well as the more highly alloyed grades such as Type 321, 347, 316, 309, 310 and the manganese-stabilized grades Type 201 and 202. Like the ferritic grades, the austenitic steels are relatively low in strength in the annealed condition. They are not hardenable by heat treatment, and their structure remains almost completely austenitic. However, cold working improves their strength.

Austenitic grades are subject to intergranular carbide precipitation when held within or cooled slowly through the temperature range of 800 to 1500° F. Sensitization results in deterioration of corrosion resistance at grain boundaries because of localized depletion of chromium in these areas. Grades have been developed which contain either a very small amount of carbon (the ELC grades) or stabilizing elements (titanium or columbium) that combine preferentially with carbon to prevent the formation of chromium carbide. Stabilized grades include Type 321 (titanium stabilized) and 347 (columbium stabilized).

The editors acknowledge the assistance of John S. Thorpe, applications development engineer, Allegheny-Ludlum Steel Corp., and engineers at Armco Steel Corp. in preparing this report.

Welding Austenitic Steels

Unless the ELC or stabilized grades are employed, the sensitized areas which occur near welded joints will be severely attacked by corrodents such as phosphoric acid, phosphate slurries, fertilizer dust, nitric acid, sulfite liquors, liquors, fatty acids, lactic acid, sulfurous acid, acetic acid and nitric-hydrofluoric acid pickling solutions. If the operating tem-

Table I – Stainless Steels for High-Strength Welded Structures and Components

	Composition								Typical
Type or Grade	C	Mn	Si	Ni	Cr	Mo	V	Other	Yield Strength (0.2% Offset)
430	0.10	1.00(max.)	1.00(max.)	0.50(max.)	17.00	—	—	—	40,000 psi.
201	0.12	6.50	1.00(max.)	4.50	17.00	—	—	0.22 N	50,000
202	0.12	9.00	1.00(max.)	5.00	18.00	—	—	0.22 N	50,000
301	0.10	2.00(max.)	1.00(max.)	7.00	17.00	—	—	0.15 N	40,000
304	0.05	2.00(max.)	1.00(max.)	10.00	19.00	—	—	—	35,000
321	0.06	2.00(max.)	1.00(max.)	9.5	18.00	—	—	Ti 6×C min.	33,000
347	0.06	2.00(max)	1.00(max.)	9.5	18.00	—	—	Cb 10×C min.	35,000
316	0.08	2.00(max.)	1.00(max.)	12.00	17.00	2.50	—	—	40,000
310	0.18	2.00(max.)	1.50(max.)	20.50	25 00	—	—	—	35,000
410	0.12	1.00(max.)	1.00(max.)	0.50(max.)	12.5	—	—	—	145,000
418	0.17	0.50(max.)	0.50(max.)	2.00	13.00	0.50(max.)	—	3.00 W	150,000
422	0.22	0.65	0.35	0.70	12.00	1.00	0.25	1.00 W	180,000
1 MoV	0.25	0.50	0.50	0.70	12.00	1.00	0.30	—	190,000
PH 15-7 Mo	0.070	1.00(max.)	1.00(max.)	7.00	15.00	2.50	—	1.2 Al	215,000
17-7 PH	0.070	1.00(max.)	1.00(max.)	7.00	17.00	—	—	1.2 Al	195,000
17-4 PH	0.070(max.)	1.00(max.)	1.00(max.)	4.00	16.00	—	—	4.00 Cu, 0.15-0.45 Cb+Ta	190,000
AM-350	0.10	0.90	0.40	4.20	17.00	2.75	—	0.10 N	165,000
AM-355	0.13	0.95	0.50(max.)	4.35	15.50	2.75	—	0.10 N	180,000
A-286	0.05	1.35	0.95	26.00	15.5	1.25	0.30	0.20 Al, 2.00 Ti, 0.003 B	100,00)

perature of the structure lies within the sensitizing range (800 to 1500° F.), then the stabilized grades are preferable since even the ELC analyses will develop harmful carbide precipitates if exposed for a sufficient length of time.

Properties		
Ultimate Tensile Strength	Elongation (in 2 In.)	Applications
70,000 psi.	30%	Furnace flues, nitric acid handling equipment, recuperators, oil burner parts, chemical plant equipment.
110,000	50	Trucks, trailers, railway cars, food handling equipment.
100,000	50	
110,000	70	Truck and bus bodies, railroad cars, roof drainage.
90,000	75	Food handling, kitchen and dairy equipment, welded wire pickling baskets.
85,000	55	Parts for aircraft and rocket engines, exhaust collector rings, pipe and tubing for exhaust manifolds, tailpipes, hot-air ducts, cryogenic tanks.
93,000	50	
82,000	65	Equipment for paper, chemical and petroleum industry, fuel tanks.
80,000	57	Furnace equipment (for reducing atmospheres, gas-turbine combustion liners, heat exchangers, chemical plant equipment.
180,000	15	Steam turbine blades, tanks and pressure vessels.
165,000	16	Compressor blading and wheels, jet engine rings.
240,000	12	
240,000	10	
235,000	7	Jet engine thrust reversers, pressure vessels, missile frames, aircraft structural parts, garbage disposals.
210,000	9	
200,000	14	Landing hooks for aircraft, landing gear, aircraft structural parts, fuel tanks, cryogenic tanks, pressure vessels.
205,000	13	Aircraft structures, hydraulic system parts, pressure vessels, flexible bellows.
215,000	18	Aircraft structures, jet engine compressor parts, pressure vessels.
145,000	25	Gas turbine buckets, afterburners, cryogenic tanks.

The choice of filler metal for welding the austenitic grades of stainless steel is usually confined to Type 308, 309 or 310. Such analyses which contain higher percentages of chromium and nickel than the base metal allow for some loss of these elements during welding. When welding Type 321, columbium-stabilized Type 347 filler metal should be used since practically all the titanium content is lost in traversing the welding arc. Welding electrodes that contain stabilizing elements are recommended when maximum freedom from sensitization is needed.

Postweld Heating

Welds in austenitic stainless steels are often heat treated to relieve stresses which may occur as a result of the heating and cooling effects of welding. This heat treatment will also redissolve chromium carbides which have precipitated during welding. Some stress relief can be obtained by heating to temperatures as low as 700° F.; for maximum effect, however, the temperature should not be less than 1550° F. To redissolve carbides, temperatures should be held at about 1850° F. for the low-alloy Type 301, 302, 304, 321 and 347 and to 2000° F. for the more highly alloyed grades such as Type 309 and 310.

The mechanical properties across welds in austenitic stainless steel are essentially identical to those of the base metal. A slight decrease in ductility will be noted, however.

Martensitic Stainless Steels

Although the martensitic steels are normally alloys of iron, chromium and carbon such as Type 410 and 420, they may also contain small amounts of nickel as does Type 431. They are hardened by heat treatment and may reach ultimate tensile strengths as high as 220,000 to 250,000 psi., still retaining good ductility, toughness and relatively good resistance to corrosion.

In welding these grades, one must again consider metallurgical characteristics. Because of their low thermal conductivity and high thermal expansion, martensitic stainless steels can experience rather high internal stresses during heating and cooling as in welding. Volume changes which occur as a result of phase transformations during hardening create additional stresses which, if not taken into account, may cause cracking of the welds.

To minimize these effects, the hardenable grades are usually preheated within the range of 200 to 600° F. and postheated between 500

Table II – Properties of Welded and Heat Treated Modified 12% Cr Stainless Steel

Type or Grade	Postweld Treatment	Yield Strength (0.2% Offset)	Ultimate Tensile Strength	Elongation (in 2 In.)
12MoV	Tempered 4 hr. at 875° F.; air cooled(a)	186,200 psi.	239,000 psi.	10.7%
	1850° F., 15 min.; air cooled; 900° F. for 4 hr.; air cooled(b)	201,500	253,000	5.3
422	1900° F., 30 min.; double 2-hr. temper at 800° F.	191,300(c) 188,350(d)	247,850(c) 241,400(d)	9.5(c) 6.5(d)
	1900° F., 30 min.; double 2-hr. temper at 900° F.	191,000(c) 188,000(d)	256,900(c) 249,400(d)	10.3(c) 8.3(d)
	1900° F., 30 min.; double 2-hr. temper at 1000° F.	173,850(c) 173,150(d)	216,250(c) 213,400(d)	7.3(c) 5.5(d)

(a) Material welded: 0.100-in. sheet, heated to 1850° F., air cooled, then + 4 hr. at 900° F.
(b) Material welded: 0.100-in. sheet, as annealed.
(c) Base-metal specimens from thin-walled pressure vessels.
(d) Butt-welded specimens from thin-walled pressure vessels.

and 700° F. Postheating also tempers any martensite formed in heat-affected zones and improves weld ductility and toughness. If weld ductility is more important than strength, postheating may be carried out between 1100 to 1500° F. Slow cooling from 1500° F. down to 1100° F., followed by air cooling to room temperature, results in maximum stress relief and minimum hardness and strength. Slow cooling from the welding temperature may also be employed for stress relieving. Either of the latter two treatments is in effect a full annealing treatment for martensitic stainless welds.

Welded structures can be heat treated to a variety of strength levels depending on the tempering temperature chosen. Weldments are hardened by air cooling from about 1800 to 1850° F., followed by tempering to a maximum of 700° F. for greatest hardness and strength or to 1100 to 1400° F. for best ductility at the expense of strength. Tempering treatments should not be carried out within the range of 700 to 1100° F. because of the "885° F. embrittlement" effect which causes a significant decrease in ductility and impact strength. In addition, strength drops off so rapidly above 700° F. that it is difficult to produce consistently the desired level of strength.

Filler metals of the same composition as the base metal (adjusted for changes in composition which occur during welding) are recommended for high-strength applications. When ductility is of greatest importance, the austenitic rods such as Type 308 can be used.

Modified Grades Available

Several modified 12% Cr martensitic steels have been developed for applications such as structural parts for jet engines and compressor and steam turbine blades which require strength properties higher than those of the regular martensitic stainless grades, particularly at elevated temperatures. Additions of tungsten, molybdenum and nickel are made to improve resistance to tempering so that these steels may be used up to 1000° F.

The modified grades, which include Greek Ascoloy, Type 422 and 422 M and 12MoV are very similar to Type 410, 420 and 431 as far as their metallurgy, heat treatment and weldability are concerned. Table II lists the properties which may be obtained in welded structures of two typical steels in this group. It should be emphasized that careful preheating and postheating are required to obtain best weld ductility.

Precipitation-Hardening Grades

Precipitation-hardening stainless steels have received considerable attention in recent years. They have been of particular interest in the aircraft and missile industry because of their excellent combination of strength and corrosion resistance. Most of the weldable grades that are commercially available fit into these categories: martensitic (17-4 PH, PH 14-4 Mo); semiaustenitic (AM-350, AM-355, 17-7 PH, PH 15-7 Mo); austenitic (A-286, HNM). The

Table III – Mechanical Properties of Welded A-286 Sheet*

Condition	Test Temperature	Yield Strength (0.2% Offset)	Ultimate Tensile Strength	Elongation	
				in 2 In.	in ½ In.
Annealed	Room	41,000 psi.	94,000 psi.	38.0%	—
Annealed and aged	Room	117,000	155,000	22.0	—
Annealed and aged	800° F.	93,000	138,000	18.0	—
Annealed and aged	1000	87,500	131,000	18.0	—
Annealed and aged	1200	88,000	103,500	13.0	—
As welded	Room	39,000	87,500	16.0	26.0%
As welded and aged	Room	93,000	132,100	4.0	11.0
As welded, solution treated and aged	Room	93,500	134,400	10.0	18.0
As welded and aged	800	88,000	98,500	3.0	8.0
As welded and aged	1000	82,000	93,000	2.0	8.0
As welded and aged	1200	83,000	86,000	2.0	10.0

*0.078 in. thick.

hardening mechanisms of these steels generally involve precipitation, an austenite to martensite transformation or a combination of the two.

The martensitic precipitation-hardening grades are martensitic at room temperature and thus provide a strong base for further hardening by precipitation. The latter treatment plays a dual role in that it stress relieves martensite and precipitates a submicroscopic phase. In the age-hardened condition, these alloys are stronger, tougher and more corrosion resistant than they are in the solution-treated condition.

How Semiaustenitic Grades Are Strengthened

Semiaustenitic precipitation-hardening stainless steels are hardened by aging, transformation of austenite to martensite or a combination of the two. In the annealed condition, AM-350, for example, contains about 15% ferrite in an austenitic matrix. In the hardening treatment, the austenite transforms to martensite – the major strengthening effect. During tempering, precipitation hardening causes a minor increase in strength and hardness. AM-355 is quite similar; it has, however, only about 5% or less delta ferrite in the austenitic matrix. Heat treatments are also similar, but AM-355 is capable of higher strength.

Hardening of AM-350 and AM-355 is achieved through control of the M_s temperature by composition and by choice of solution treating or annealing temperature. By annealing the material at 1710° F., the M_s will be located at or near room temperature. Upon cooling to −100° F., the austenite-martensite transformation occurs. Subsequent tempering at 850 to 1000° F. improves strength and toughness. This procedure is termed the SCT treatment.

Table IV – Properties of Cold Rolled Austenitic and Semiaustenitic Stainless Steel

Type or Grade	Yield Strength (0.2% Offset)	Ultimate Tensile Strength	Elongation (in 2 In.)
301 Annealed	40,000 psi.	110,000 psi.	60.0%
¼ Hard	75,000*	125,000*	18.0*
½ Hard	110,000*	150,000*	12.0*
Full Hard	140,000*	185,000*	9.0*
AM-350 CRT†	190,000	210,000	10.0
AM-355 CRT	210,000	230,000	12.0
SCCRT‡	280,000	290,000	2.5
XH§	330,000	350,000	1.0
17-7 PH CH 900	260,000	265,000	2.0
PH 15-7 Mo CH 900	260,000	265,000	2.0

*A.I.S.I. minimum properties.
†Cold rolled (about 25% reduction), tempered.
‡Subzero cooled, cold rolled, tempered.
§Cold rolled (about 60 to 70% reduction), tempered.

An alternative method, the DA treatment, can also be used. After being annealed at 1710° F., the material is heated to 1375° F. Precipitation of carbides occurs and the M_s temperature rises to somewhat above room temperature. Cooling from 1375° F. effects the hardening transformation after which a suitable tempering treatment is applied.

Similar treatments are applicable to 17-7 PH and PH 15-7 Mo although recommended temperatures may differ. (*Continued on p. 118*)

*Thorium as a Nuclear Fuel**

IT WAS RECOGNIZED EARLY in the history of nuclear reactors that additional fissionable isotopes, Pu^{239} and U^{233}, could be produced in a reactor from the fertile materials, U^{238} and Th^{232}. It was also recognized that the long-term importance of nuclear fuels for power production depends upon our ability to use not only the original fissionable material provided by nature, but also at least some appreciable part of the much more abundant materials which could be converted into fissionable isotopes.

The average thorium content of the earth's crust is three to four times that of uranium; on the other hand, their geochemical properties and the manner in which deposits were formed in higher-than-normal concentrations indicate that uranium reserves and potential annual production rates would be several times those of thorium at current prices. In other words, the unit cost would have to go up appreciably before thorium would be equal in availability to uranium. These are average situations of ore availability – obviously, there are local situations in which thorium is much more plentiful and thus of much greater interest as a nuclear fuel.

Nuclear Properties – The fact that nature provided a starter in the form of U^{235} in natural uranium is at least partially offset by the relatively better nuclear properties of U^{233} (produced from thorium) in comparison with Pu^{239} (produced from natural uranium) for reactors operating primarily on thermal neutrons. This nuclear advantage is in two forms: *(a)* more neutrons are produced per neutron absorbed which means, for comparable losses, more neutrons are available for conversion of new fuel, and *(b)* the positive temperature coefficient associated with low-level resonance in Pu^{239} is avoided. This latter effect is particularly important for reactors which are to operate at high temperatures.

In addition to the nuclear advantages of the transformed fissionable material, thorium metal – being of cubic structure – is more resistant to radiation damage than uranium metal. In both cases, however, alloys or ceramic forms for fuel materials seem to be required in order to make low-cost nuclear power. This is an area which is especially important in the development of thorium for power reactors.

Fuel Materials – Materials specialists say that portions of the thorium production cycle need improvement. For example, techniques for melting and casting thorium on a large scale are inadequate. Unsound castings result in difficulties during fabrication of fuel.

Fuel materials under development include both metal alloys and ceramics. Thorium-uranium alloys with up to 20% (by weight) uranium have been found to have good dimensional stability when irradiated at 680° C. to an estimated burn-up of 2.9 at.%.

Investigations of thorium alloys for power-reactor applications are directed toward development of thorium-uranium alloys of improved mechanical properties at elevated temperatures using alloying elements of low thermal neutron cross section. Addition of such materials has been found to increase the mechanical strength of thorium-uranium base alloys significantly.

Plutonium-thorium alloys also are of interest. Use of plutonium as the initial fissionable material rather than U^{235} permits easy chemical separation of the U^{233} produced. Plutonium is soluble in thorium; thus the advantages of solid-solution strengthening are achieved with the addition of a few percent of plutonium to the thorium.

Ceramic Materials – Development of thorium-containing ceramics includes work on a wide variety of materials such as mixed oxides, carbides, and silicides of thorium and uranium or thorium and plutonium. A potential advantage of the mixed thorium-uranium oxide fuels compared with straight uranium oxide is a lower rate of release at elevated temperatures of xenon because of the lower vapor pressure of the thoria.

Greatest emphasis in the area of ceramic fuel materials containing thorium is being placed on dispersed uranium and thorium carbides in a graphite matrix. This work includes development of suitable cladding, coating, and encapsulating techniques for containment of fission products. Techniques involving coating of individual small particles with materials such as alumina or pyrographite look particularly attractive.

Future Prospects – While work on thorium-based fuel materials is expanding, it must be recognized that much less effort has been devoted to this cycle than to the materials involved in the uranium-based fuel cycle. Fortunately, many of the lessons learned in uranium development are either applicable or at least helpful in the development of thorium which, in fact, is a less complex material.

Although thorium has many handicaps in its competition with uranium, it has certain advantages to offer also, so it is still a definite contender. Its value can be known only after considerably more work has been done and, in particular, after experience has been obtained operating reactors and servicing facilities.

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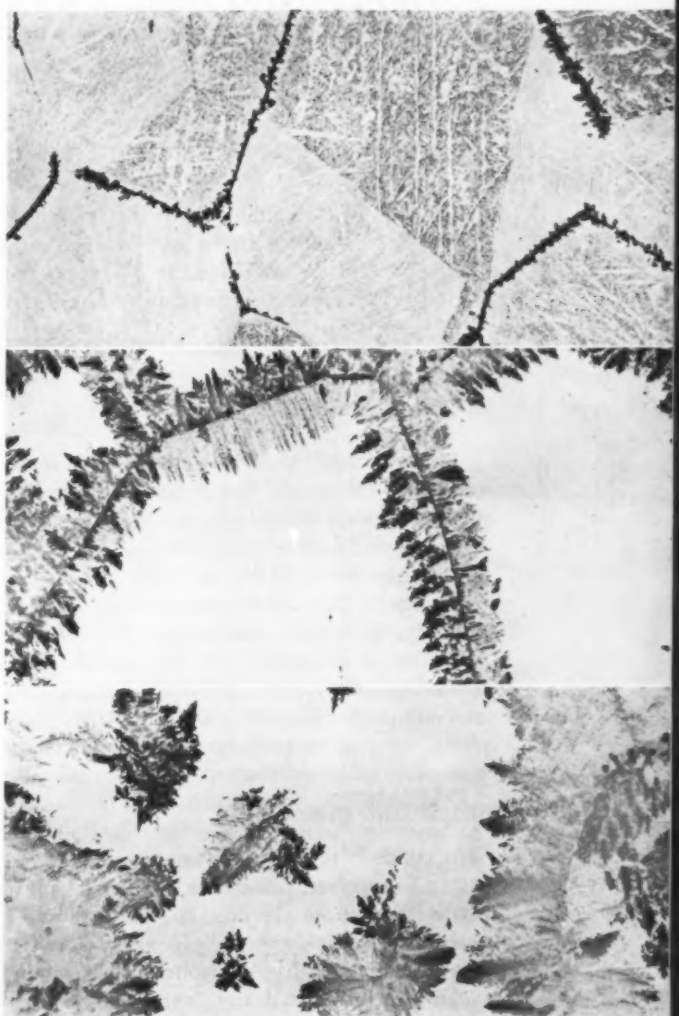
*Excerpts of remarks made by Ulysses M. Staebler, senior assistant director, Division of Reactor Development, U. S. Atomic Energy Commission, before the 6th Nuclear Congress, in Rome, Italy.

Prizewinner in 15th Annual A.S.M. Metallographic Exhibit

The Pearlite Reaction in a High-Alloy Steel

*By R. R. Russell and W. C. Hagel**

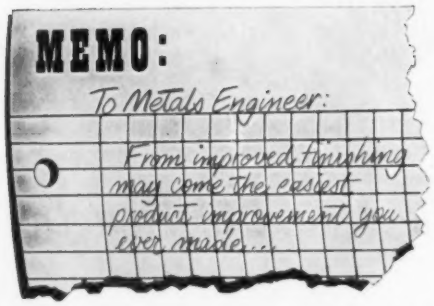


IN LINE WITH THEORY, one would predict that the nucleation sites for pearlite are saturated first at grain corners and edges, then along grain surfaces (including specimen edges), and finally at random points within the grain. However, this sequence has rarely been observed in practice because the over-all transformation is ordinarily completed before the nucleation sites inside the grains come into play. Even when separate intragranular nodules have been found, further sectioning usually revealed their attachment to a grain boundary. Yet, as the three micrographs at right show, the complete sequence can be observed in large grains which are transformed at a temperature below the "nose" of the TTT curve where the growth rate is low.

To prepare the specimens for photography, thin disks of a steel containing 9% Cr and 1% C were austenitized for 12 hr. at 1200° C. (2200° F.), isothermally transformed in deoxidized lead for various time intervals at 575° C. (1070° F.), and quenched in room-temperature water. Metallographic specimens were initially polished on rotating paper laps charged with 9-micron and 3-micron diamond abrasive paste, respectively. For intermediate polishing, we employed a cloth-covered lap charged with 1-micron diamond abrasive paste. Finally, the specimens were finished on a cloth lap with an aqueous suspension of 0.1-micron alumina. They were etched in a 100-ml. solution of ethyl alcohol containing 1 g. picric acid and 5 ml. hydrochloric acid, and photographed at 150 × (reproduced here at 75 ×).

The top micrograph shows the steel after 1 hr. at 575° C. (1070° F.). As predicted, pearlite has nucleated at the grain corners and edges, but has not yet occupied all the grain surfaces or the specimen edge. The matrix is martensitic except for a short distance ahead of the advancing colonies of pearlite where carbon depletion permitted the retention of austenite. Three hours of isothermal transformation produced the structure illustrated by the center micrograph. All of the grain boundaries are now covered with dendritic-appearing slabs of orientation-dependent pearlite, although there are some untransformed regions along the specimen edge. Finally in the bottom micrograph, after 6 hr. of transformation at 575° C., the specimen edges are covered with pearlite, and new nodules are starting to form intragranularly. No boundary attachments were revealed on further polishing and etching.

*Metallographer and Metallurgist, General Electric Research Laboratory, Schenectady, N.Y.



No. 8 in a Series on Better Finishing

How to Get the Most From Phosphating Systems—III

*By GEORGE H. PIMBLEY**

Of all the phosphating techniques, the "iron" phosphate systems – either dip or spray – are the most widely used. They are simple in operation and maintenance, and usually require less equipment than the zinc and manganese phosphating systems. (L14b)

THE TERM "IRON PHOSPHATING" is somewhat of a misnomer, but it describes a phosphating process which requires a minimum of technical skill and knowledge to operate. These advantages account for its wide use – more than any of the other phosphating systems. Actually, the term describes a process that produces a phosphate of the metal being treated; no other metal enters the coating. On iron and steel, the coating will be an iron phosphate; on zinc or cadmium surfaces, it is the phosphate of either element.

Simple Bath Compositions

In contrast to the heavy-metal phosphating systems described previously, the "iron" phosphate systems are simple. Basically, they use baths of relatively high pH which contain small amounts of free phosphoric acid so that pickling is minimized and, instead, the formation of a coating is favored. This can be done simply by employing an alkali metal dihydrogen phosphate such as sodium ortho-dihydrogen phosphate. Add a detergent, catalysts and corrosion inhibitors and the result is a bath for iron phosphating.

Obviously, these solutions are just a step beyond those which contain phosphoric acid alone, but the coatings they form on metal parts increase the adhesion of paints and organic finishes. Should the paint be abraded, then the continuous film of insoluble phosphate will block the corrosion under the paint thus preventing it from popping off or peeling and blistering.

*Group Leader, Metal Surface Conversion Coatings, Research and Development Dept., Turco Products, Inc., Wilmington, Calif. The first two parts of this three-part article appeared in *Metal Progress* in August and September.

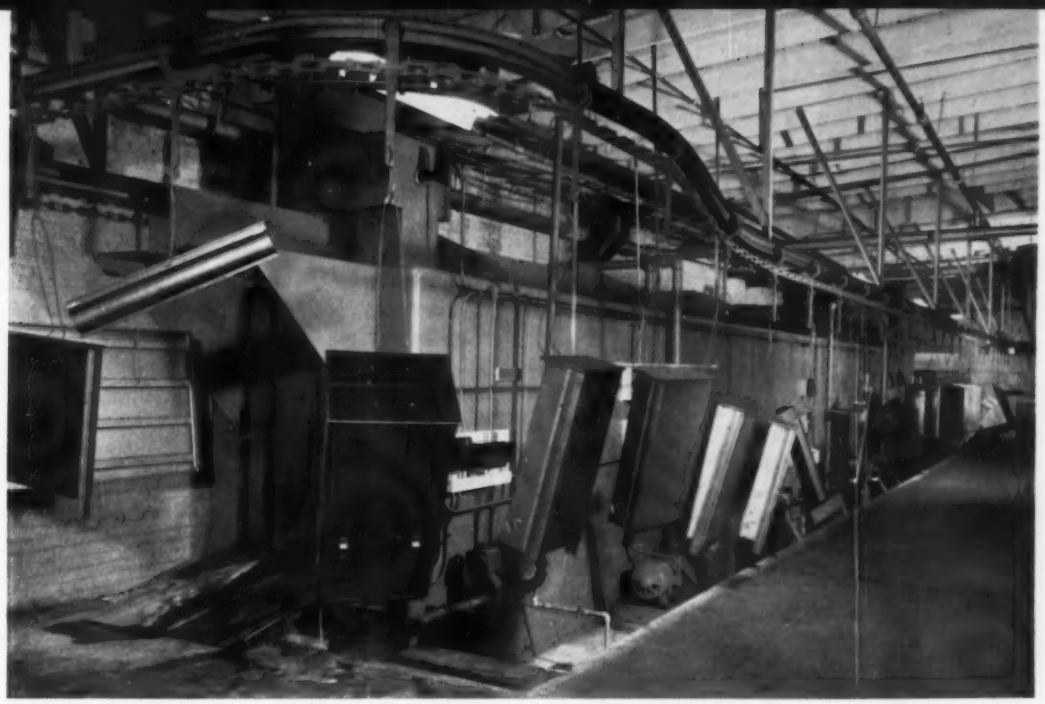


Fig. 1 – Components for Steel Office Furniture Enter Three-Stage Phosphating Line at Bentson Mfg. Co., Aurora, Ill. Iron phosphating – usually applied in a three-stage system like this – is the most widely used phosphating method

Iron-Type Phosphating Baths

Iron phosphate baths differ from those of the zinc and manganese phosphates previously discussed in that they are expected to accomplish both cleaning and phosphating. In most instances, the equipment is limited to three simple spray-washer or dip stages. A minimum of control is necessary, and testing and maintenance procedures are not complicated.

The processing baths do not have the property of partial self-regeneration possessed by zinc and manganese phosphate baths. Iron phosphate baths continuously accumulate grease and compounds of relatively high pH that remain in the solution instead of sludging out; hence, these baths have a limited life expectancy, and must be completely dumped when the contaminants have accumulated to such an extent that they seriously impair coating efficiency.

Iron phosphate coatings may be applied by either spray or dipping. Ordinarily, the number of stages in the installation will be either three, four or five. For spray application the equipment will usually consist of conventional spray-washer cabinets, with the work moving through by conveyor. Dipping is done in mild steel tanks, the bath being agitated by compressed air.

In three-stage installations, the first stage (and sometimes the second) consists of the phosphating bath. (Usually the second stage is a water rinse.) The third stage is, in all instances, a dilute inhibitive bath, such as a chromic-acid solution or a 50:50 mixture of phosphoric acid with chromic acid.

Because there are no provisions for cleaning the parts before they enter the phosphating system, the first stage must serve as both cleaner and phosphater. Occasionally, sandblasting or degreasing will be used before the work comes to the phosphating installation, but the primary job of cleaning (and phosphating) is left to the first stage.

Four-stage installations may include two successive phosphating stages, followed by a water rinse in the third stage and inhibitive final rinse in the fourth. Occasionally, the first stage may consist of alkaline cleaning bath, followed by a hot-water rinse, a phosphating bath, then an inhibitive rinse in the fourth stage. When the fourth stage performs the dual function of a water rinse and inhibitive rinse, it should be dumped and a fresh solution made every day.

In the usual arrangement of the five-stage installation, the first consists of hot alkaline cleaner, then a hot-water rinse, a phosphating stage, a cold-water rinse, and an inhibitive rinse. Regardless of the number of stages, all of them should be agitated. Compositions of the alkaline cleaner (if any) and the final inhibitive rinse are the same as those used in zinc and manganese phosphating systems.

Fig. 2 – Paint Adhesion and Corrosion Resistance of These Bowls and Hoods for Outdoor Barbecues Are Improved by Applying a Phosphate Coating in a Three-Stage Spray Washer. The work is done at Storall Mfg. Co. at Inglewood, Calif.

Making Up a New Bath

New baths are prepared by stirring the phosphating compound into cold or warm water. Then it is mixed thoroughly by circulating it through the spray system or by some other means of agitation. Foaming can be prevented by heating the bath to the specified working temperature before sending the solution through the spray system.

The makeup of dip baths is quite similar, but the higher concentration will usually be considerably higher than for spray solutions. Mixing is aided by air agitation; here again, however, the bath should be heated to the working temperature before being agitated.

Once the bath has been mixed, it is a good idea to check its strength and to make sure that all of the solids are in solution. There is no necessity for breaking in iron phosphating baths; they are ready for work immediately after being prepared.

Best Operating Procedures

Contact time in spray systems is usually held to a minimum of 60 sec. in the cleaning and phosphating stages, and 30 sec. in the water rinse and inhibitive rinse stages. The immersion time for dipping ranges from 5 to 10 min. in the cleaning and phosphating stages and 30 sec. to 1 min. in the water rinse and inhibitive rinse stages.

Operating temperatures depend on the formulation of the solution, but most producers of phosphating chemicals recommend 140 to 160° F. for spray cleaning and phosphating baths, 150 to 170° F. for the dip cleaning and phosphating baths, 120 to 140° F. for water rinses, and 140 to 180° F. for the final inhibitive rinse. Spraying pressure should be 20 to 30 psi. in all stages. The extent of agitation of dip baths is a compromise; it should be sufficient to bring the bath into contact with every point of the work surface but not so extreme that it causes excessive foaming.

Quality of the coating is also affected by the position of the work pieces. All significant surfaces should be vertical; totally enclosed areas which will shut out the bath solutions must be avoided. The work must move steadily between stages and into the drying oven at the end, else there may be blotches and rusting, especially if the work is stopped between stages.

pH Is Important

As pointed out previously, an iron phosphating bath has a limited life expectancy. How long it will perform efficiently depends on several factors such as the type of work surface, the nature of the soil, whether or not the bath must do both cleaning and phosphating, the amount of work passing through the bath, and the quality of the maintenance.

During operation, the phosphating bath should be tested frequently for concentration and pH. The pH value is observed ordinarily by sensitive, narrow-range test paper, although a pH meter is more accurate. The bath will show fluctuating pH values, depending upon the nature of the phosphating chemical, its concentration, replenishment schedule and age of the bath. Sometimes pH is also moderately affected by the hardness of the water.

What might be considered optimum pH value for any given set of circumstances will depend on these factors and also on whether cleaning or phosphating is the most important action desired. Generally, pH is higher for the relatively low concentrations used for spraying, and will be lower for dipping con-

centrations. For best cleaning pH should be held between 4 and 5.5, and for optimum phosphating action it should range between 3 to 4.5. The matter is often a compromise between what is desired in the way of cleaning and what is desired in the way of phosphating action. When experience has shown that a certain pH range gives the best results for any given bath and any given job, then it is well to try to hold it within that range by replenishing the phosphating chemicals, supplementing these by occasional additions of phosphoric acid in amounts not exceeding ¼ pint per 100 gal. of bath at any one time.

In addition to these replenishments, water should be added as necessary to make up for evaporation. Accumulation of ferrous iron is ordinarily not a problem with the iron phosphate baths nor is the accumulation of heavy sludge. If sludge does build up, then it should be removed from the tank occasionally. Any grease floating on top of the bath should be removed in the morning before the bath has become heated.

Discard Spent Baths

Despite all maintenance care, the time will come when no replenishment or addition will keep the bath at a satisfactory performance level. When this point is reached, it is necessary to discard the bath and make a new one. This can be done in the following manner: With three-stage installations the phosphating bath is completely discarded and the tank well cleaned and flushed out with water. The walls of the tank should be wiped down and freed of grease. In spray washers the nozzles should be taken out and thoroughly cleaned. While the nozzles are out, the spray system should be operated with clear water to flush out the riser and header pipes thoroughly.

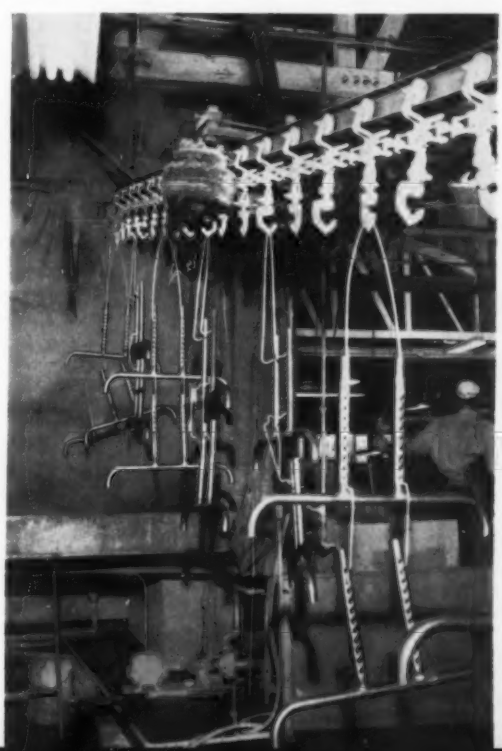
In installations having two successive phosphating stages, the first one should be dumped because it catches the most grease and will be the more contaminated of the two. Its tank, the nozzles and pipes are then thoroughly cleaned and flushed out. After the first tank is thoroughly cleaned, the second-stage solution is pumped into it. This bath still possesses considerable life. The second-stage tank, spray line, and nozzles are then thoroughly cleaned and flushed out with clear water, and a fresh bath is made up for it. When this procedure is followed, the partially spent bath becomes the first stage to catch most of the incoming grease; the fresh, second phosphating bath finishes the cleaning job and performs most of the phosphating action.

Testing the Coatings

Ordinarily unpainted iron phosphate coatings are only inspected visually and rubbed with a piece of white facial tissue. When the bath has satisfactorily performed its functions of cleaning and light phosphating, there should be no smut or gray powder on the tissue if it is rubbed across the coating with moderate pressure. Coatings on hot rolled steel are an exception; they will usually show a slight rub-off even though they are good coatings. Iron phosphate coatings usually cannot be scratched with a finger nail, except at times when the base metal is a soft or hot rolled steel. The coating will be very thin, nearly amorphous in texture, and will exhibit some mottling and iridescence, ranging from a golden yellow through gray, to deep bluish-gray.

Because the coating is very thin and inherently less corrosion resistant than good crystalline heavy-metal phosphates, it cannot be expected to perform as well in salt-spray and water-immersion tests. Nevertheless, it is quite common to require equal performance; hence, careful operation and maintenance should be exercised.

Fig. 3 – Busy Phosphating Line at Virco Mfg. Co. in Gardena, Calif. Treats Table Legs for School Furniture Before Painting



Short Runs

Flash Welding Copper to Steel

By HERMANN W. STIEGLITZ*

THE REDUCTION OF ALUMINA to aluminum requires transmission of large amounts of electricity at about 100,000 amp. through carbon anodes into carbon-lined pots which contain alumina dissolved in cryolite. To carry such high current efficiently, each anode connector is made of a bar of copper, measuring 1¼ by 3 by 40 in., which is attached at one end of a steel anode core or billet, 6 in. in diameter by 12 in. long. The anode connector is fastened to a copper busbar by mechanical connectors.

It has been standard procedure to join the steel billet to the copper connector by bolting. Making this connection takes considerable time because optimum electrical contact is required. Joining by welding is obviously a much faster method, but it has presented difficulties that, until recently, could not be resolved by any existing equipment.

With the emergence of new electronic controls for flash welding machines, a good welded joint is now possible. These controls synchronize the transition between flashing and upset which is imperative if there is to be assurance of consistent quality and a strong bond.

In flash welding, the normal procedure is to clamp the copper bar on the movable platen and the steel billet on the stationary platen of the machine (Fig. 1). The gap is adjusted according to the burn-off of copper that is expected, and the pieces are usually preheated, as determined by trial, prior to flash welding. With the start of the machine cycle, electronic controls take over, closing the platen at the correct speed, and exerting a pushup force of 100,000 lb. at the right moment to produce a sound weld.

In a recent production run, copper connector bars were reduced in cross section at one end to 2½ by 1¼ in. to provide increased resistance in the weld area. The anodes were welded under the following conditions:

Clamping force	100,000 lb.
Upset force	58,800 lb.
Preheat	70% of weld temperature
Preheat time	24 sec.
Upset current	51,800 amp.
Flashing time	16 sec.
Chill time	1 to 2 sec.

A cross section of a welded anode (Fig. 2) shows a penetration of ⅞ in. made by the copper bar into the end of the steel billet, with a loss in length during upset and "flash-off" of ½ in.

*Vice-President of Engineering, Thomson Electric Welder Co., Lynn, Mass.

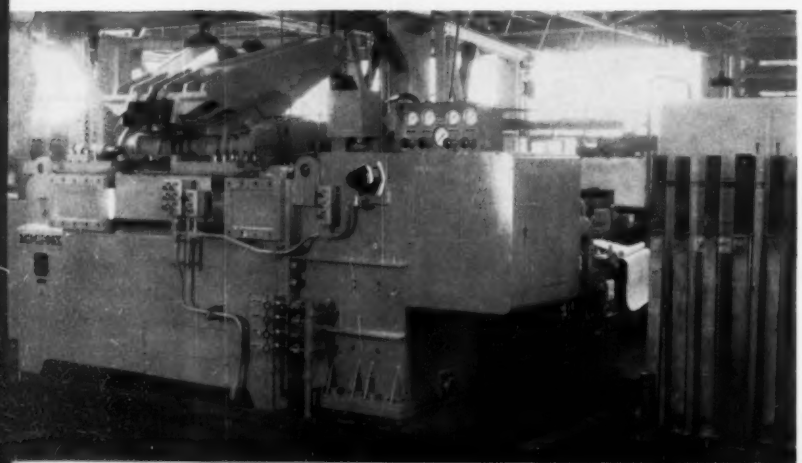
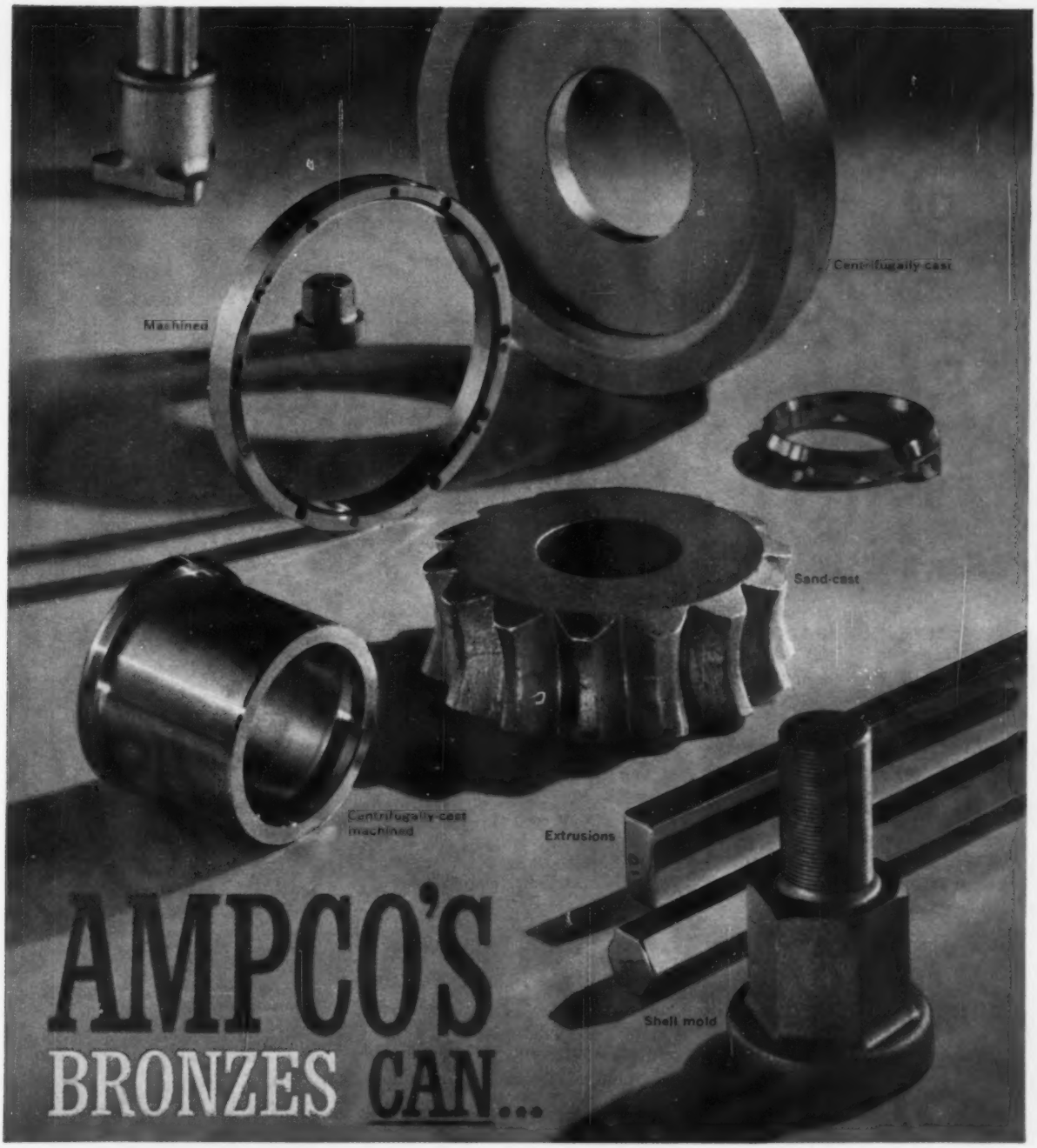


Fig. 1 – A 600-Kva. Welding Machine Used in Welding Anodes (Right). Flash initiation and upset force are automatically controlled

Fig. 2 – Cross Section of an Anode Shows Penetration of Copper Connector Bar Into Steel Core or Billet



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Circle 1882 on Page 48-B

LETTERS to the EDITOR

CORRESPONDENCE INVITED ON ANY METALLURGICAL SUBJECT • CORRES PONDENCE INVITED ON ANY METALLURGICAL SUBJECT • CORRESPONDEN CE INVITED ON ANY METALLURGICAL SUBJECT • CORRESPONDENCE INVIT ED ON ANY METALLURGICAL SUBJECT • CORRESPONDENCE INVITED ON A NY METALLURGICAL SUBJECT • CORRESPONDENCE INVITED ON ANY MET ALLURGICAL SUBJECT • CORRESPONDENCE INVITED ON ANY METALLURG ICAL SUBJECT • CORRESPONDENCE INVITED ON ANY METALLURGICAL SU

In "A New High-Strength Aluminum Alloy", by J. A. Nock, Jr., Marshall Holt and D. O. Sprowls, which appeared in the September issue, the micrographs in Fig. 3 on p. 89 were inadvertently transposed by the editors. The micrograph on the right shows intergranular attack in 2219-T 62 sheet and that on the left shows intergranular attack in insufficiently aged 2219-T 62.

Power From Gas-Cooled Reactors

CANOGA PARK, CALIF.

In the Letters to the Editor columns in June (p. 114), C. W. Funk of Aerojet-General Nucleonics comments on "Power From Gas-Cooled Reactors", which appeared in the April 1960 issue of *Metal Progress*. In the first paragraph, Mr. Funk states: "No other power reactor currently in operation achieves outlet coolant temperatures in the range of 1200° F. . . ." I should like to correct this impression; liquid-metal cooled reactors have been and are operating in the range of 1000 to 1200° F. coolant outlet temperatures, and have generated 1000° F. steam in at least one instance, using liquid sodium as a coolant. These reactors are designed for power systems with expected lifetimes in the tens of thousands of hours. I trust this information clarifies the position of liquid-metal cooled reactors in regard to temperature capability.

R. W. DICKINSON
Director
Sodium Reactors Department
Atomics International

"Upsetting" Situation

COLUMBUS, OHIO

In the course of a research program conducted by Messrs. Van Orsdel and Noethlich and the writer, an unusual thermal cycling effect was noted. Two wires of dissimilar alloys were butt welded. The joint was given a severe thermal cycling treatment over many hours. The result is shown in Fig. 1. The joint on the bottom has been "upset" by the action of stresses created by thermal cycling. Here is a way to upset metal without mechanical working! Perhaps one of your readers might uncover a useful application of this phenomenon in our industrial complex.

R. B. FISHER
Chief
Powder Metallurgy Division
Battelle Memorial Institute

(More Letters on p. 118)

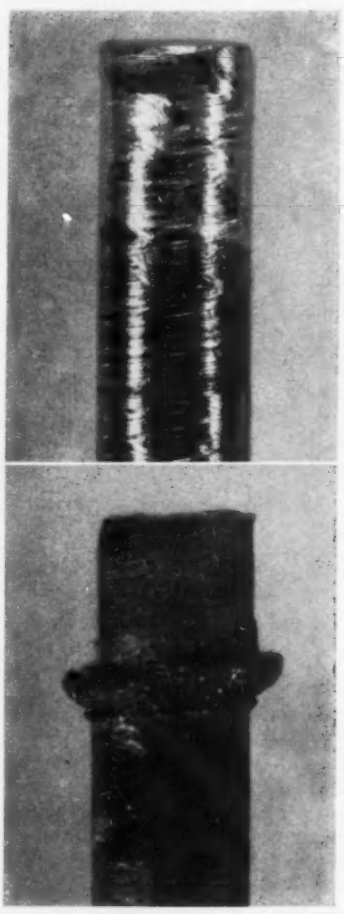
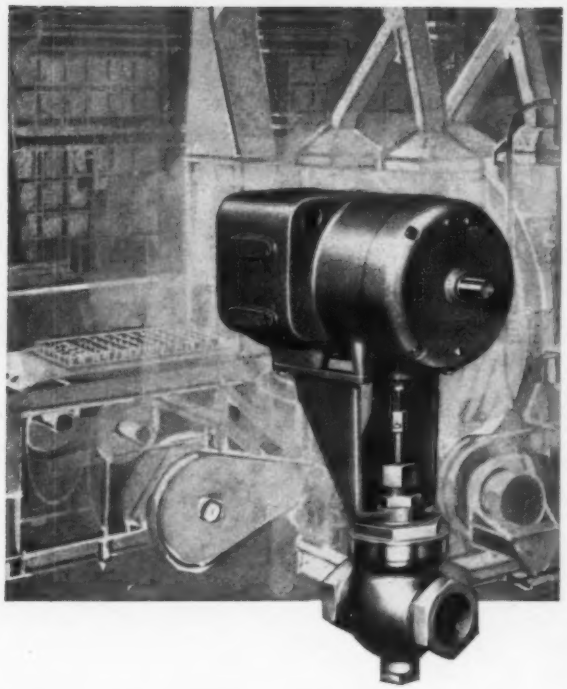


Fig. 1 – Effect of Thermal Cycling. (Top) Butt welded wires. (Bottom) "Upset" joint. 15 ×



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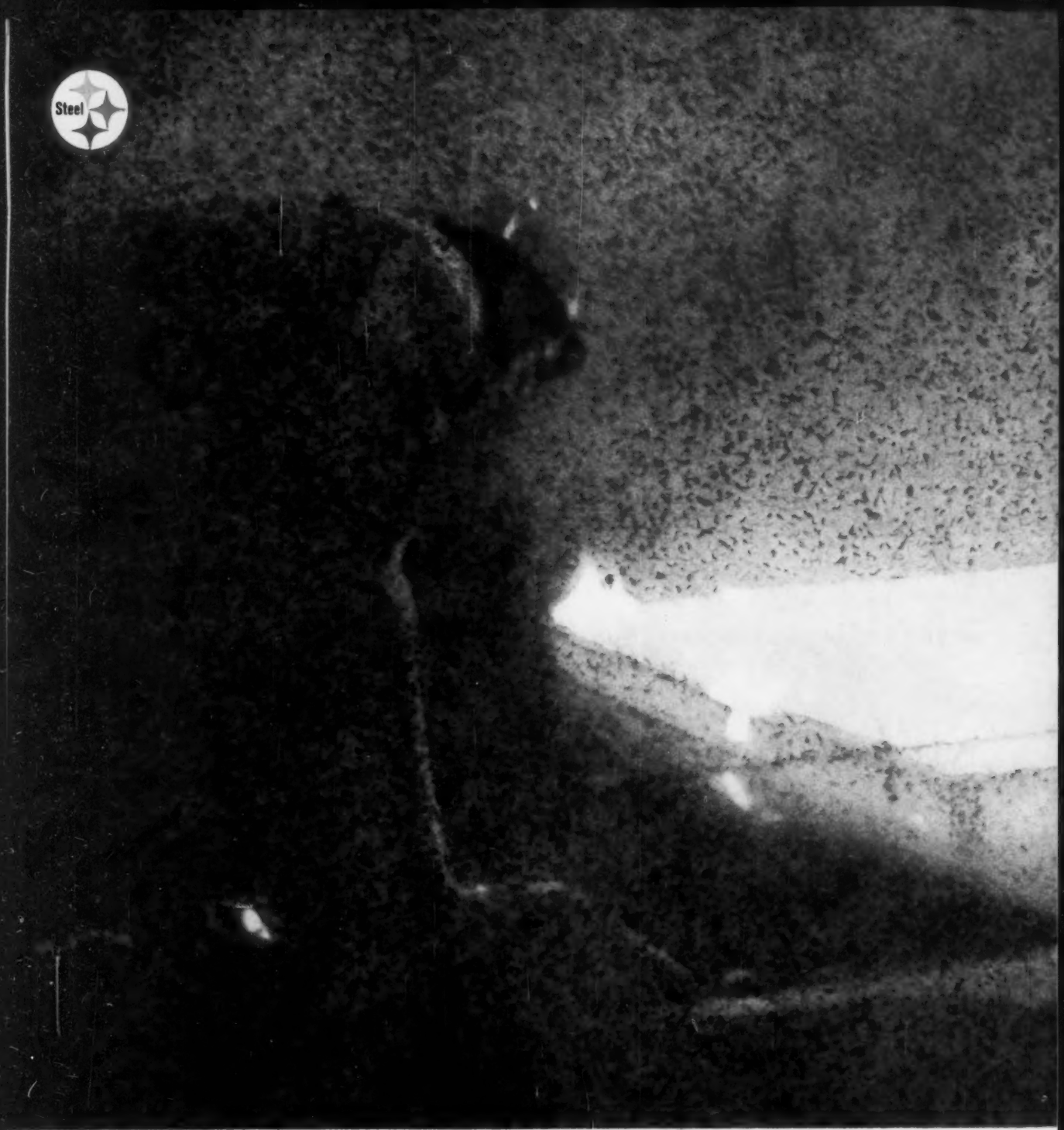
See us in Sweet's 1961 Product Design File, Section 7b-Min.



THE EXTRA MEASURE

PHOTOGRAPH BY PAUL WELLER

Thoroughness. By a steelmaking specialist ■ On Lukens' 206-inch mill the world's largest steel plates are improved by the cross-rolling technique. Rolled lengthwise. Carefully measured. Turned and rolled sideways. Measured again. Lukens' cross-rolling procedure develops more uniform metallurgical properties. The extra measure of strength and quality essential to the fabricators of vital steel plate projects ■ Thoroughness is a Lukens habit, as well, in researching the best steels for difficult applications. Working with your engineers on problems of design and fabrication. Helping you select the best steel for the job from Lukens' complete line of carbon, alloy, armor and clad steel plates. Heads. Plate shapes ■ Thoroughness is one of many characteristics that make Lukens

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Circle 1885 on Page 49-B

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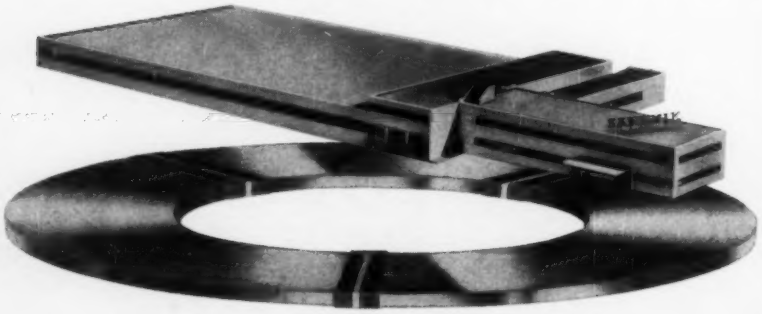

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Circle 1886 on Page 48-B

Some Reagents Explode

WESTBURY, L.I., N.Y.

In "Some Reagents Explode" (p. 114, July 1961), it was stated that an explosive hazard exists when a mixture of nitric acid, acetic acid and acetone are allowed to stand for several hours.

This same type of reaction was observed in our laboratory minutes after the reagent was prepared. The mixture of 10 ml. concentrated nitric acid, 10 ml. glacial acetic acid and 20 ml. chemically pure acetone reacted spontaneously about 2 min. after mixing with an evolution of heat, nitrous and nitric oxide fumes.

This occurred when the mixed acids were poured into the acetone. We were able to control this hazard by first cooling the acids and then slowly pouring into a cold water jacketed beaker of acetone. The temperature of the mixture should be kept below 25° to prevent reaction. The etchant was discarded after use.

G. D. LANE
G. J. DURMANN
Metco Inc.

Stainless Steel . . .

(Continued from p. 105)

Welding Semiaustenitic Steels

Neither preheat, control of interpass temperature nor postweld annealing are necessary in welding the semiaustenitic precipitation-hardening steels. Sound welds with excellent mechanical properties have been consistently produced by using the welding techniques common to the austenitic stainless grades. Cleaning, joint preparation, joint fit-up and jiggling procedures are also the same. Either annealed or heat treated steel may be welded.

AM-350 and AM-355 can be welded by the inert-gas, tungsten-arc process (with or without filler metal), covered-electrode arc welding or submerged-arc welding. Only the inert-gas, tungsten-arc process is recommended for 17-7 PH and PH 15-7 Mo. These steels can also be satisfactorily resistance welded in the annealed or hardened condition; only minor adjustments need be

ADAPTABLE

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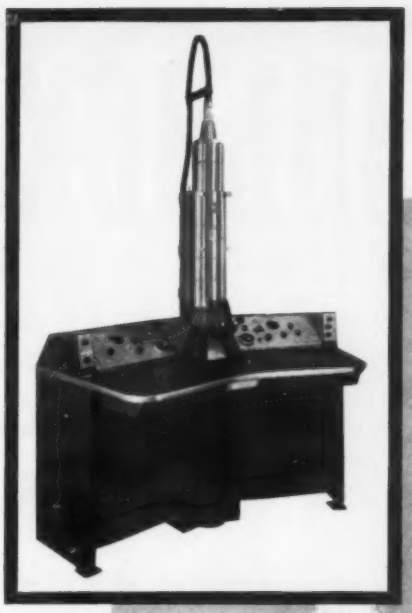

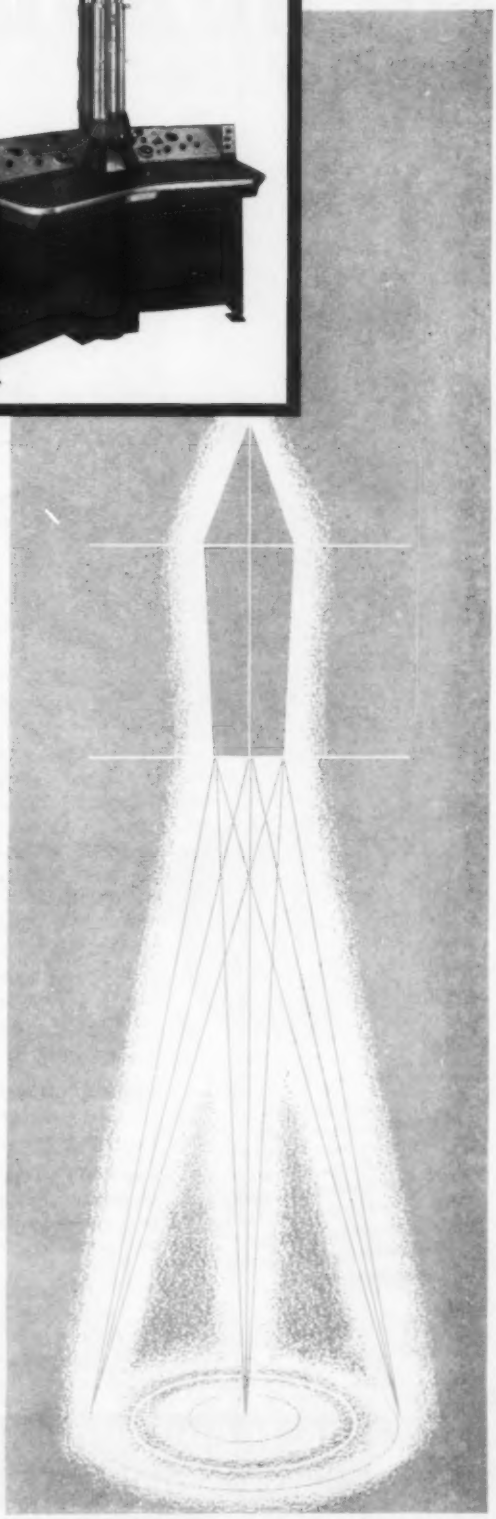

The adaptability of the RCA Electron Microscope is one of its most valuable features. Through foresighted design, even the early models have been adapted with new parts and accessories to prolong their useful lifetime. A double condenser lens was recently announced as a new accessory and soon a Universal Stage for hot and cold specimen analysis will be available.

As a specific example of the EMU's adaptability, the basic instrument provides for switching from microscopy to selected area diffraction. The new electron diffraction chamber—an accessory which is easily slipped into position to become an integral component of the unit—now makes it possible to perform transmission and reflection type diffraction studies. Users rate the EMU-3, thus equipped, as one of the best electron diffraction cameras available today.

Such adaptability is one of the many reasons why more of these reliable RCA instruments have been sold than all other electron microscopes. Added to this is the availability of a nation-wide service organization, plus the assistance of the Applications Laboratory in Camden for the benefit of customers everywhere. A NEW LEASING PLAN now makes it possible to obtain all RCA scientific instruments with no down payment, low monthly terms and a favorable option to buy. Our representative will be glad to call on you at your convenience. Or write for additional information: RCA, Scientific Instruments, Dept. **B-72,** Building 15-1, Camden, N. J. In Canada: RCA VICTOR Company, Limited, Montreal.

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Circle 1887 on Page 48-B

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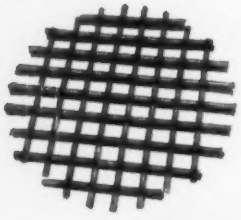

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Circle 1888 on Page 48-B

Stainless Steel . . .

made in welding current or cycles to compensate for the difference in electrical resistivity as compared with the austenitic stainless steels. Tension shear strength of material that is hardened, then spot welded, is of the same general level as material welded and then hardened.

Austenitic PH Steels

The last group of precipitation-hardening steels, typified by A-286, are essentially iron-chromium-nickel alloys which are austenitic in structure. These steels, however, contain varying amounts of titanium and aluminum which promote an age-hardening mechanism by precipitation of Ni_3Ti particles. Heating solution-treated or annealed A-286 to 1325° F. for 16 hr., for example, effects the precipitation of Ni_3Ti which significantly improves the room and high-temperature strength without adversely affecting ductility and toughness.

Although alloys of this type have relatively low room-temperature strength compared with the martensitic and semiaustenitic steels, they retain their strength to considerably higher temperatures and, accordingly, are stronger between 1000 and 1300° F. Also, because of their austenitic structures, they possess better cryogenic properties than the more brittle martensitic and semi-austenitic steels and the lower-strength austenitic steels.

A-286 can be successfully welded in thin sections and, under conditions of low restraint, by either resistance, inert-gas tungsten-arc (with or without filler metal), inert-gas, consumable-electrode or flash butt welding techniques.

In inert-gas, tungsten-arc welding, filler metals such as Hastelloy W, A-286 or Timken 16-25-6 are used. Filler metal for the shielded consumable-electrode method may be A-286, Type 310, 316 or 347 stainless steel, Timken 16-25-6, Inconel 132 or other austenitic steels. For strength approaching that of the parent metal, A-286 filler wire should be used. Restraint should be kept as low as possible because constituents at the grain boundaries in the weld metal can cause hot cracking.

Heat treatment of welded A-286

normally follows the regular procedure for unwelded material. Solution treatment may be performed at either 1800 or 1650° F. The former solution-treating temperature is used where long-time properties such as creep strength or stress rupture strength are of greatest importance. Where short-time yield or tensile strength are more important, the latter temperature is preferred. After solution treating, the welds should be aged for 16 hr. at 1325° F. Table III (p. 105) indicates the strengths obtainable in welded A-286 components.

Cold Worked Stainless Steels

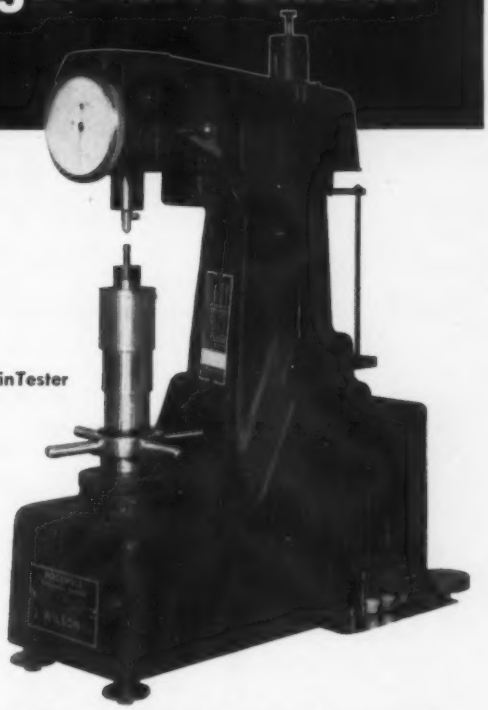
The austenitic stainless steels and the semiaustenitic steels which are austenitic in the annealed condition can be strengthened by cold working (followed by tempering) to relatively high strength levels. Type 301 and 302 in a full range of tempers, as well as AM-350 and AM-355 in the CRT, SCCRT and XH conditions and 17-7 PH and PH 15-7 Mo in the CH 900 condition are typical examples of these steels. It will be noted in Table IV that very useful properties can be produced by cold rolling the austenitic stainless steels or by combinations of subzero cooling, cold rolling and tempering AM-350 and AM-355.

Fusion welding of such steels creates weld zones which have essentially the same strength characteristics as annealed material. For this reason, resistance welding is usually employed for such joining problems. However, it has been shown* that strength levels considerably higher than those obtained in annealed material can be considered for design purposes.

In addition, fusion welding can be used to fabricate such steels if the weld area is reinforced by increasing the metal thickness in the vicinity of the weld joint. This may be done by upsetting, chemical milling or machining and by resistance welding doublers in this area. The weld metal can also be peened or work hardened to increase its strength. Another procedure which may be used is to orient the fusion weld in a direction oblique to the loading direction.

*"Weld Strength of Cold Worked Stainless Steels", by L. Stemann and E. E. Weismantel, *Welding Journal*, Vol. 39, No. 10, p. 438s.

Two Hardness Testers in a Single Instrument



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Circle 1884 on Page 48-B

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Circle 1890 on Page 48-B

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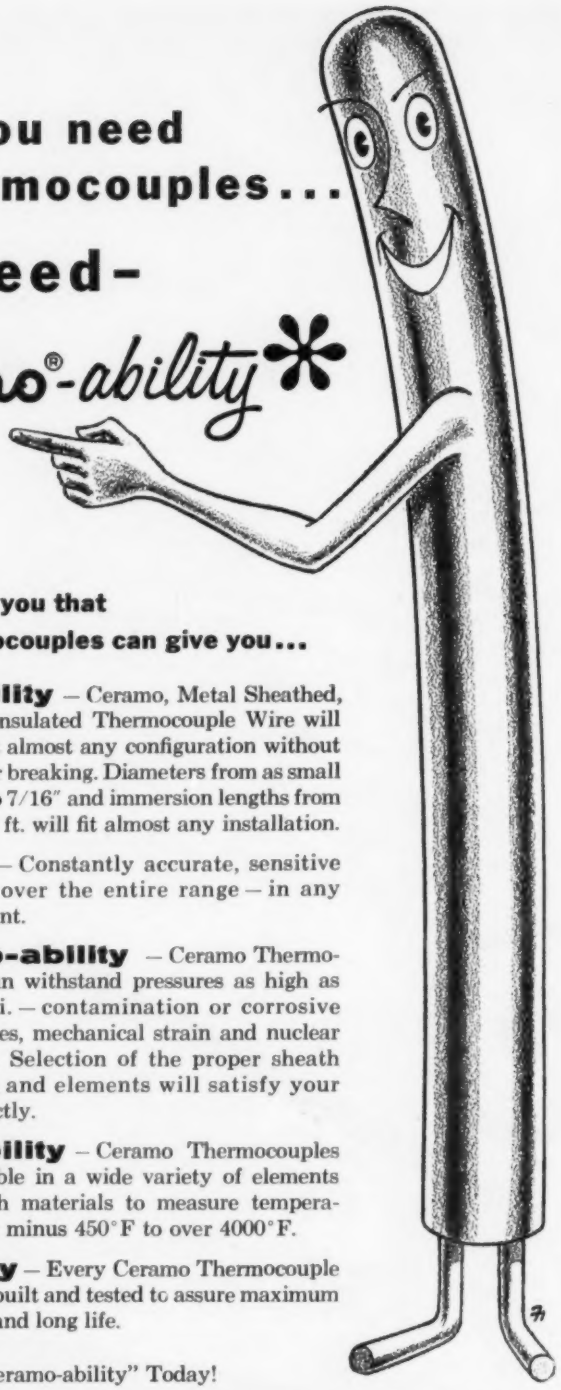

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Circle 1891 on Page 48-B

Personals . . .

Robert T. Eakin – now vice-president in the engineering and construction division of Koppers Co., Inc., Pittsburgh.

Richard W. Douglass – from Battelle Memorial Institute, Columbus, Ohio, to metallurgist in the Metals Div., National Research Corp., Cambridge, Mass.

B. Dean Bowen – joined the technical staff of Allvac Metals Co., Monroe, N. C.

Roger M. Blough, chairman of the board of directors and chief executive officer of United States Steel Corp. – appointed chairman of the Metals Div. of the $50,000,000 Columbia-Presbyterian Medical Center Development Fund.

Thomas F. Berry – a member of General Electric's engineering and science program for the last year, now working in the materials and processes laboratory at Schenectady, N. Y., assigned to metallurgical developments associated with arc and gas welding.

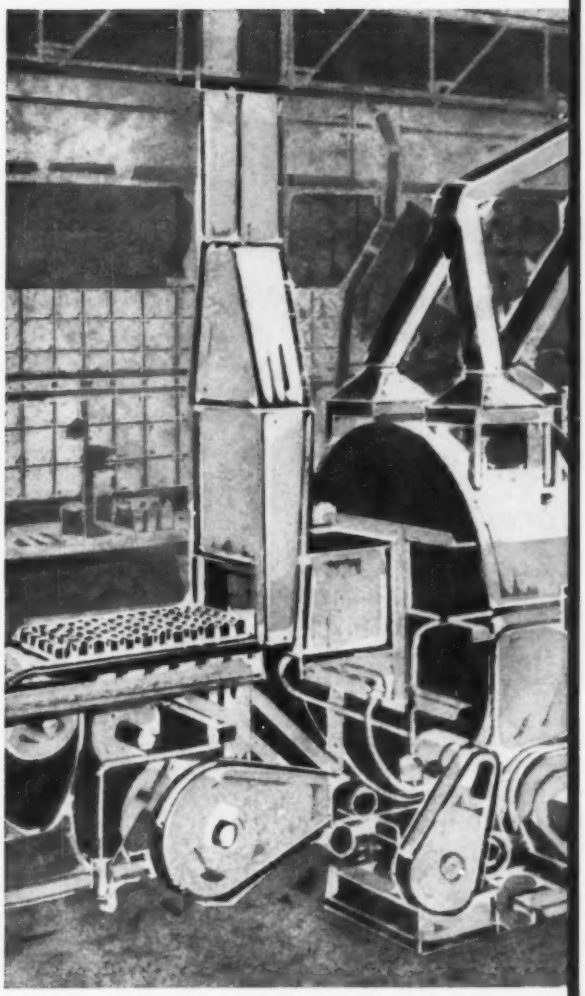
J. M. Bates – now senior staff engineer in the engineering department of Union Carbide Chemicals Co., South Charleston, W. Va.

Sanford Baranow – from the Aircraft Nuclear Propulsion Dept., General Electric Co., Evendale, Ohio, to the materials department of Tapco, a division of Thompson Ramo Wooldridge Inc., Cleveland.

William F. Aylard – from director of engineering to vice-president of Chase Brass & Copper Co., a subsidiary of Kennecott Copper Corp., Waterbury, Conn.

Clifford Amend – named metallurgist at Ajax Magnethermic Corp., Youngstown, Ohio.

Roland P. Koehring – presented a plaque honoring his pioneering contributions to the advancement of powder metallurgy by the Metal Powder Industries Federation. This marked the first presentation of the Powder Metallurgy Pioneer Award. Mr. Koehring recently retired as section engineer in charge of research at the Delco Moraine Div. of General Motors in Dayton, Ohio, after 40 years with the company.



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First in Control

SINCE 1885

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Circle 1892 on Page 48-8

Metals Engineering DIGEST

Interpretative Reports of World-Wide Developments

Metal Surfaces . . . How They Look and How They Behave

*Reported by M. V. NEVITT**

A variety of experimental techniques – ranging from field ion microscopy to magnetic measurements – are being employed to learn how surface structure affects properties. This report of a recent symposium discusses the instruments currently used to probe the structure of metal surfaces.

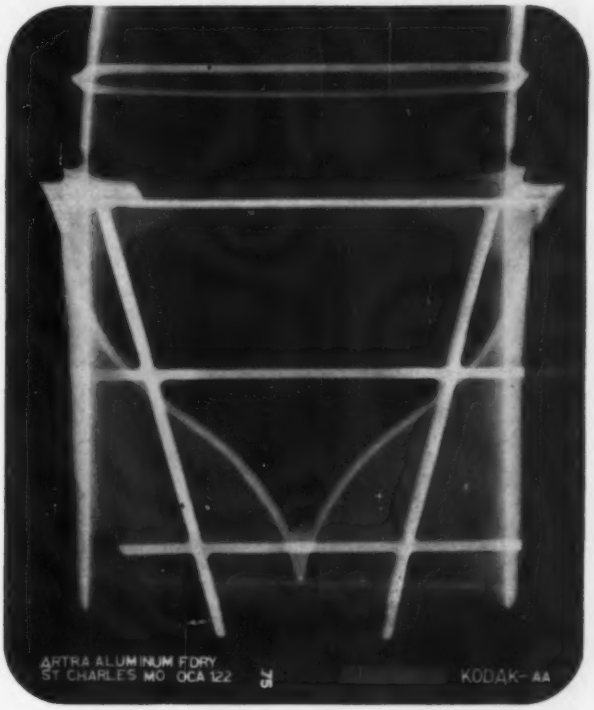
ALTHOUGH THE STUDY of metal surfaces as a distinct branch of metal physics is a new concept, basic aspects of surface preparation go back as far as the 17th century. Such well-known scientific names of the 1600's as Hooke, Herschel and Newton are associated with investigations of the techniques of surface grinding and polishing. Newton voiced an early opinion that the processes of grinding and polishing were essentially the same – they both removed surface irregularities. This simple but in fact erroneous point of view remained in vogue until 1921 when Beilby published his "Aggregation and Flow of Solids". This paper stated that abrasive particles used in grinding removed material by scoring, whereas polishing leads to an alteration and plastic flow of the surface layer (called the "Beilby layer").

With this introduction R. K. Hart (Argonne National Laboratory) set the stage for the Sixth Annual Regional Seminar of the Chicago-Western Chapter ASM on "Properties of Metallic Surfaces". Two hundred scientists and engineers from the Midwest heard Dr. Hart – who was opening speaker and moderator – and five other prominent scientists discuss how metal surfaces look, how they

*Alloy Properties Group Leader, Metallurgy Div., Argonne National Laboratory, Argonne, Ill. Mr. Nevitt, who is 1961 seminar chairman of the Chicago-Western Chapter ASM, reports on the chapter's Sixth Annual Regional Seminar on "Properties of Metallic Surfaces", held April 20, 1961, at Illinois Institute of Technology in Chicago.

To keep cool at a couple of "machs"

Photograph and radiograph of aircraft refrigeration duct cast of magnesium AZ91.



At jet speeds a problem is to keep the pilot cool. Artra Aluminum contributes this magnesium casting for a refrigeration duct, and uses radiography to assure that it is sound and dependable.

Without proper cooling in the cockpit, today's supersonic pilots would cook. Refrigeration is a "must."

Along with other components, Artra Aluminum Foundry of St. Charles, Missouri, provides this AZ91 magnesium casting for the pilot's cooling system. It is ultralight, and ultrastrong. And radiography is used to make certain that there are no flaws.

Artra has earned an outstanding reputation for fine work with materials difficult to cast. And they give full credit to the way radiography helps them to evolve casting methods that greatly reduce rejections and thus makes sure that only quality work is delivered.

Foundries, large and small, find that radiography quickly becomes a valuable asset in their operations. It can work for you, too. You can learn how by getting in touch with an X-ray dealer or writing us to have a Kodak Technical Representative call.

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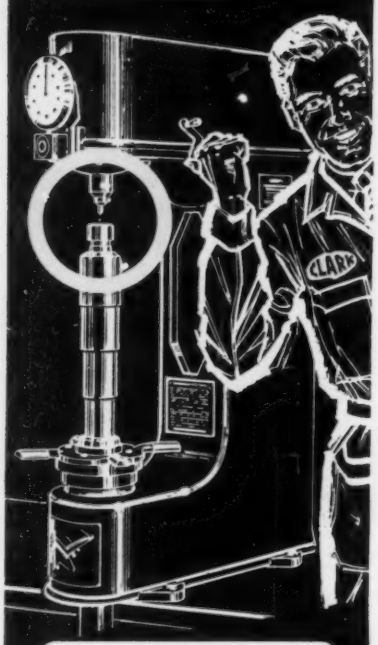

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Circle 1894 on Page 48-B

Metal Surfaces . . .

behave, how they affect physical, mechanical and chemical properties.

In considering the nature of a metal surface, one usually visualizes a close-packed atomic plane, ideally flat and part of an ideally perfect crystal. Physical reality is introduced by permitting the surface to contain defects such as dislocations, vacant sites and interstitial atoms. In addition, contamination with adsorbed gas molecules is allowed. The validity of this model has been supported by results obtained with field emission microscopy and by a variety of physical measurements.

Field Emission Microscopy

E. W. Müller (Pennsylvania State University), who was a pioneer in the use of the field electron microscope and later invented the field ion microscope, described how the latter instrument enables us to see a metal surface under enormous magnification and with a resolution which exposes details of atomic dimensions. The microscope, depicted schematically in Fig. 1, looks at the

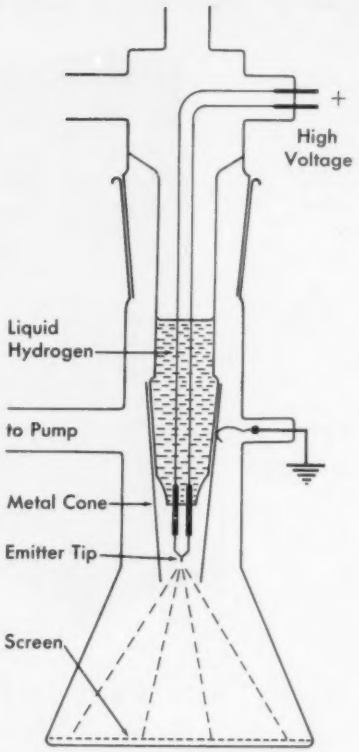
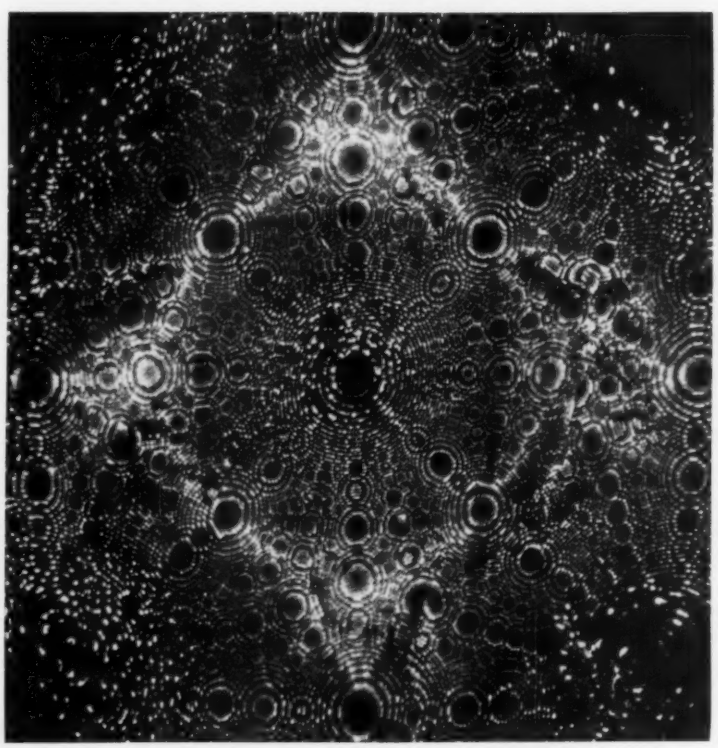


Fig. 1 – Field Ion Microscope

Fig. 2 – Platinum Crystal in (001) Orientation After Recovery From Stress. 750,000 ×



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HOUGHTON QUENCHANTS

The role of the quench in precision heat treating

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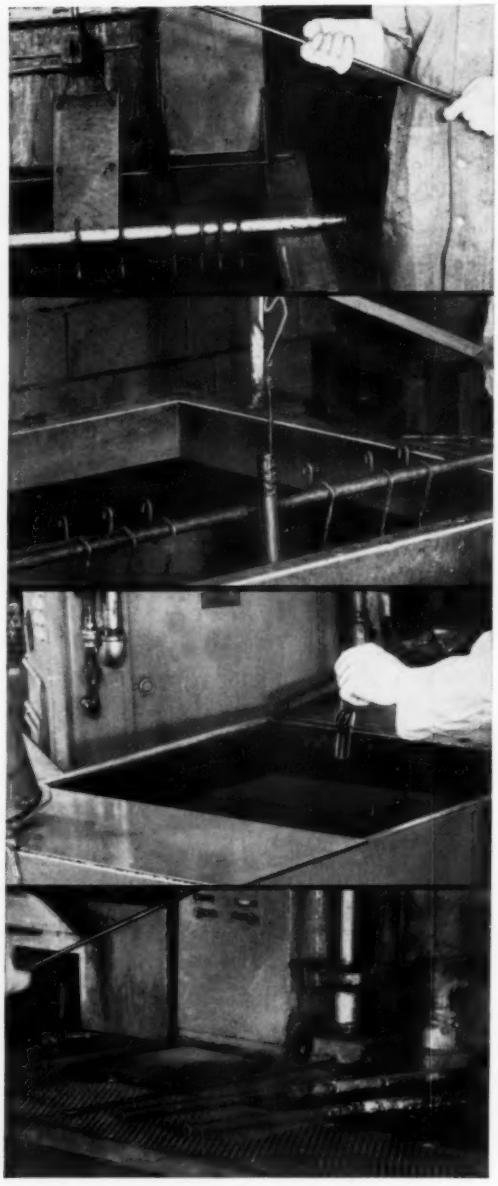

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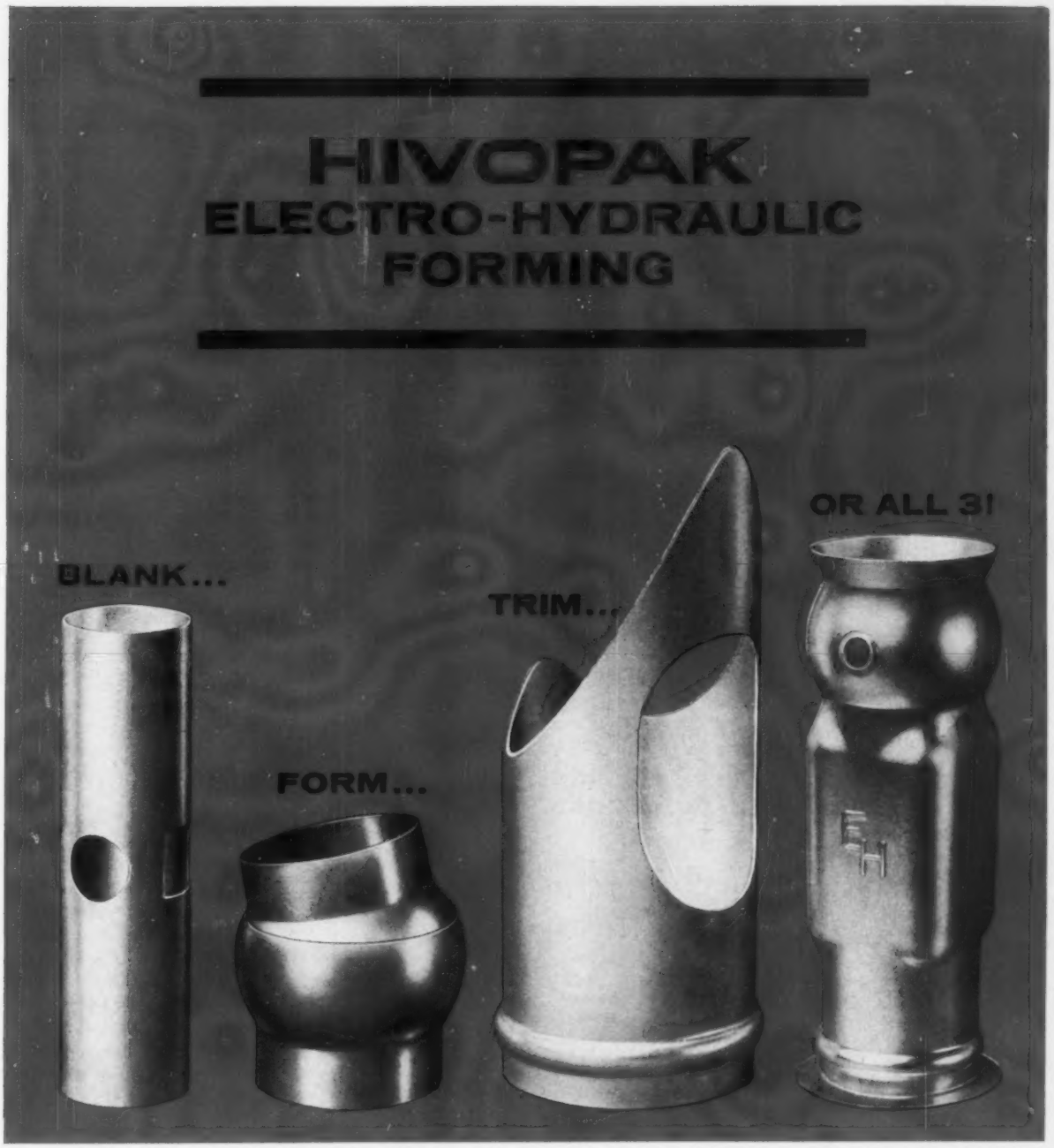

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Metal Surfaces . . .

tip of a needle-shaped emitter which is the specimen. The image-producing medium is supplied to the tip from the outside in the form of helium gas atoms. High voltage produces a field at the tip surface of sufficient strength to ionize the gas atoms. Under the influence of the field, ions are accelerated toward a viewing screen where they depict the place of their origin.

There are two important advantages of ions over electrons as charged particles which produce the image. The larger mass of the ion results in a wave length that is shorter than that of an electron of comparable energy; this improves the limiting resolution. Also, by having the specimen tip at liquid-nitrogen or liquid-hydrogen temperature, gas atoms, which obey Boltzmann statistics, are slowed down and stripped of a random tangential-velocity component which would produce a blurring of the image after their ionization. Electrons, following Fermi statistics, have large tangential velocities which cannot be appreciably reduced by lowering the temperature of the emitter. In practice, resolution of a field ion microscope is 2.7 A., which is the spacing of adjacent lattice atoms, as opposed to a resolution of 20 A. for a field electron microscope.

Since all metals with melting points below 1400° C. (2550° F.) evaporate when subjected to fields above 400 million v. per cm. (the field necessary to ionize helium gas), application of the microscope is limited to refractory metals. Despite this limitation, it has many important uses.

Besides showing an atomic crystal lattice directly, another contribution is the ability of the instrument to reveal individual vacancies, interstitials and dislocations. Although structural details of lattice defects and their importance in determining properties are now well known to physicists and physical metallurgists, defects could not be seen directly as long as it was impossible to see individual atoms forming a crystal lattice.

Field ion micrographs reveal individual atoms and show interstitials, vacancies and dislocations in a striking way. Figure 2 shows a field ion micrograph of a platinum crystal. The (001) plane is in the center, and at the corners are the four (111) planes. There are also more than 100 crystal facets with higher Müller indices on this crystal hemisphere, many of them resolved in single atoms. After an earlier inspection had shown that the crystal was nearly perfect, the specimen was allowed to recover at room temperature from a radial stress of 1 ton per sq.mm. produced by the electrostatic force of the imaging field. Then the micrograph shown in Fig. 2 was taken. The crystal is no longer perfect; there are numerous dislocations on the surface.

Vacancies also can be identified readily. By carefully stripping off monatomic layers (by use of field evaporation at liquid hydrogen temperature), Professor Müller has been able to count the number of vacancies in each layer and ultimately to arrive at a value for the concentration of vacancies in the specimen under study.

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METALGRAMS

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NOVEMBER 1961

COLUMBIUM -- AN OLD ELEMENT WITH NEW USES -- Although columbium was discovered by Hatchett in 1801, it did not find any metallurgical uses until the 1930's. Then, Union Carbide Metals found that columbium prevented intergranular corrosion of 18-8 stainless steels, allowing welding. Other UCM findings: (1) Columbium improved the strength and toughness of plain-carbon and low-alloy high-strength steels; (2) Columbium reduced air hardening in plain-chromium stainless steels; and (3) Columbium increased the strength of high-alloy compositions at high temperatures. These applications find wide commercial use today.

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COLUMBIUM STEELS CAPTURE HEADLINES -- Recently, a lot of interest has been shown in carbon steels containing a pinch of columbium. Up to 0.03 per cent improves strength and weldability with only a minor loss in ductility. At a price only slightly more than plain-carbon grades, the high-strength of these steels offers cost savings by permitting designers to use lighter sections. Today, columbium steels are being used in trucks and trailers, earth-moving and construction equipment, oxygen cylinders, and line pipe.

* * *

GROWTH PROBLEMS -- Columbium steels are having growing pains, though. Of some concern has been the transition temperature from ductile-to-brittle fracture. Although satisfactory low-temperature impact properties have been obtained in plate thicknesses up to 3-8 in., the transition temperature of heavier plate sections has increased. Research has shown that higher manganese contents, water quenching off the hot mill, or normalizing can improve heavier section impacts. For more information, write for the article, "Columbium in Carbon Steels," in the Fall 1961 issue of UNION CARBIDE METALS REVIEW.

For more information circle 1872 on page 488

* * *

FERROCOLUMBIUM AND COLUMBIUM METAL -- Union Carbide Metals has been producing high-quality ferrocolumbium and ferrotantalum-columbium for steel and high-temperature alloys since 1935. Now, UCM also offers electron-beam-melted ingots of columbium metal -- the purest columbium available. Columbium metal and columbium-base alloys have many potential uses. Their superior strength at high temperatures suggests many aircraft and space-vehicle applications. Their resistance to molten salts opens up chemical-equipment uses. Columbium's moderate neutron cross-section allows use in nuclear-reactor structures. Alloys of columbium are also being widely tested as superconductive materials. For more information, write for F-20,133 on ferrocolumbium, data sheet Cb-1 on columbium metal, and the article, "Mill Products Multiply," in the Fall 1961 issue of UNION CARBIDE METALS REVIEW.

For more information circle 1897 on page 488

* * *

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Circle 1898 on Page 48-B

Metal Surfaces . . .

possible to give the specimen various treatments and to make observations of various structural changes within the lattice. Fatigue, creep, slip, cathode sputtering and alpha-irradiation experiments have been carried out. The specific lattice condition does not change during observation because the tip inside the field microscope need not be exposed to high temperature.

Chemisorption Studies

Not all studies of surface behavior can be performed by direct observation of surface appearance. For example, chemisorption (adhesion of a molecule to a surface when electronic interactions between adsorbent and adsorbate occur) is a phenomenon which is advantageously studied by observations of saturation magnetization. P. W. Selwood and his associates at Northwestern University are making measurement of this kind. Small particles of nickel and cobalt with average diameters less than 100 A., and perhaps as low as 30 A, are supported in a silica gel. When a measured quantity of hydrogen is adsorbed on the surface of these particles, some of the electron spins which are unpaired in the elemental metals are paired in the bonding process. Redistributions of electronic states can be determined by measuring saturation magnetization at liquid-helium temperature and in fields up to 18,000 oersteds. Adsorption of hydrogen on particles always results in a decrease in saturation magnetization. For nickel particles, about 0.7 electron spins are paired for every hydrogen atom chemisorbed. The fractional value suggests that interacting electrons are localized near the adsorbed species; similarity of 0.7 to the number of unpaired spins per atom of pure nickel was thought to support a view of localized (covalent) nickel-hydrogen-bond formation. However, when the experiment was repeated using cobalt particles, only 0.4 electron spins were paired per atom of hydrogen chemisorbed. The interpretation used for the nickel results would suggest that every hydrogen atom chemisorbed on cobalt should pair 1, or perhaps even 1.7, 3d electrons. Both experiments can be explained by postulating the existence of a set of molecular orbitals localized around the chemisorbed hydrogen atoms and the neighboring surface atoms. Part of the hydrogen electrons go into these orbitals and the rest interact with the unpaired 3d electrons.

Two other observations—of particular interest to workers in the field of heterogeneous catalysis—concern the adsorption of hydrogen and carbon monoxide on nickel. When hydrogen is adsorbed on nickel, there is no important change in bond type as surface coverage increases, despite the fact that heat of adsorption decreases markedly. Carbon monoxide adsorbed on nickel is bonded primarily in the linear form (Ni — C — O) until coverage is fairly large, after which more than one CO molecule may be adsorbed on a single nickel atom.

Perhaps the most significant thing about these surface studies is the fact that, although there is no direct observation of the surface, one can, by following magnetic behavior of the material, make rather unambiguous interpretations of what is going on during the adsorptive process.

Etch Pits on Single Crystals

F. W. Young, Jr., (Oak Ridge National Laboratory) described experimental techniques which seem to lie somewhere between those of Müller and Selwood in terms of the subtlety of the relation between the property actually observed and the surface feature under study. He examines etch pits on crystal faces of nearly perfect single crystals of copper (treated with special etching solutions) and relates them to the presence of dislocations in crystals.

There are two motivations for establishing this relationship. First, the delineation of dislocations by etch pits enables one to study motion of dislocations caused by mechanical deformation and by annealing. Second, definition of the role of dislocations in the etching process may lead to an improved understanding of the dissolution mechanisms.

Although dislocations are of atomic dimensions, etch pits must be made large enough to be visible with an electron or a light microscope. The solution of this problem requires an understanding of

two fundamental processes for dissolution of metals: *(a)* nucleation of steps at a source, and *(b)* motion of these steps away from the source by removal of atoms from the steps into the surrounding medium.

Irrespective of the complexity of a corrosion process, it always occurs at steps. For face-centered cubic systems, a step is assumed to exist when atoms on a surface have seven or less nearest neighbors. Built-in steps are not present on close-packed surfaces; they must be nucleated there if surface reactions are to take place. Since intersections of dislocations with the surface are a source of steps it is probable that etch pits will be observed at points where dislocations intersect close-packed surfaces.

However, the nucleation of a monatomic step cannot be observed. Rather, many closely spaced steps, one inside the other, must occur before a pit becomes deep enough to be visible microscopically. It has been found that this condition is achieved when etching solutions contain certain ingredients which serve to "poison" freshly nucleated steps and prevent them from moving rapidly over a surface.

The restrictive and demanding nature of the experimental techniques is obvious: Etch pits related to intersections of dislocations can only be observed on close-packed crystal faces – and then only if the etching solution contains an ingredient which assures that the etch pits consist of many concentric steps which have been nucleated in one place before the first steps have moved very far from the source.

Since surface crystallography is important, the pits should have shapes that are related to the crystal symmetry of the etched face – that is, square pits on (100) faces, triangular pits on (111) faces, rectangular pits on (110) faces.

Impurities collect around dislocations because of interactions with the dislocation stress fields. These impurity atoms affect the extra energy available to atoms in the vicinity of a dislocation, and etch pits formed at such "dirty" dislocations differ in appearance from those formed at dislocations which do not contain impurity atoms. The latter are called "clean" dislocations. Figure 3 shows clean dislocations of the edge type (the line marked 1),

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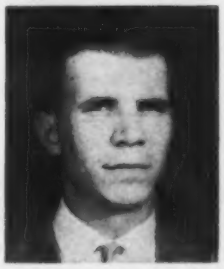

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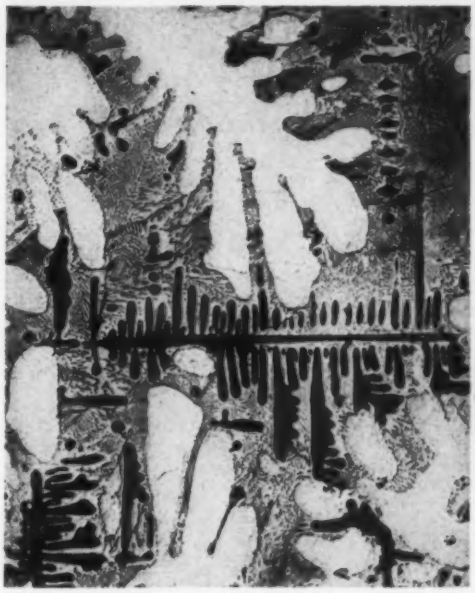

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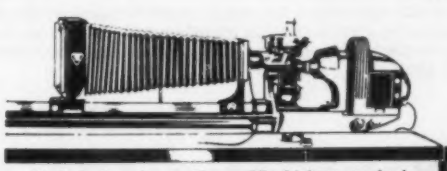

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Circle 1899 on Page 48-B

clean screw dislocations (2), and "dirty" or grown-in dislocations in the grain boundary (3).

To produce this composite array of dislocations, a crystal with a (111) flat was previously hardened by neutron irradiation and then bent to produce new edge and "clean" screw dislocations. It was then electropolished and etched in a solution which effectively reveals etch pits on (111) faces.

An important point, of course, is whether there is a 1:1 correspondence between pits and dislocations. Dr. Young's experiments, as well as those of other investigators, suggest

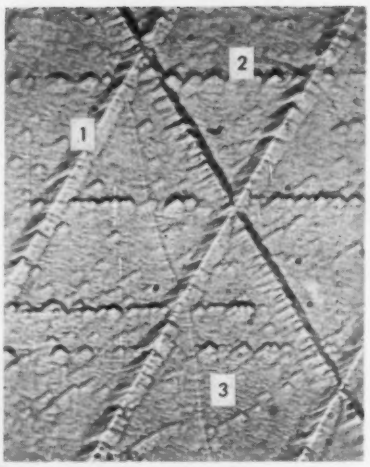


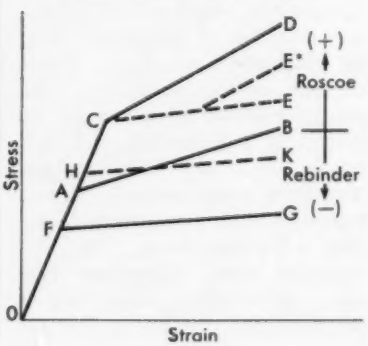
Fig. 3—Delineation of Dislocations by Etch Pits on a Copper Single Crystal. 500 ×

that agreement between numbers of pits and dislocations is at least within 20%.

Properties vs. Surface

A.R.C. Westwood (Research Institute for Advanced Studies) called attention to the fact that mechanical properties of materials are significantly affected by various surface conditions. Considering the stress-strain curve (OAB) of Fig. 4 to be that of a clean single crystal, there are two ways in which the surface can influence this curve. The presence of a solid coating on the surface will produce "Roscoe effects" (OCD and OCE) involving: *(a)* an increase in the flow stress, *(b)* variation in subsequent rate of work hardening — increase or decrease, and *(c)* a reduction in ductility. Alternatively, adsorbed polar molecules and liquid-metal films produce "Rebinder effects" (OFG in Fig. 4): *(a)* a decrease in yield or flow stress, *(b)* a decrease in subsequent rate of

Fig. 4 — Influence of "Roscoe" and "Rebinder" Effects on Stress-Strain Curve of a Clean Metallic Single Crystal



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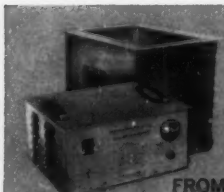

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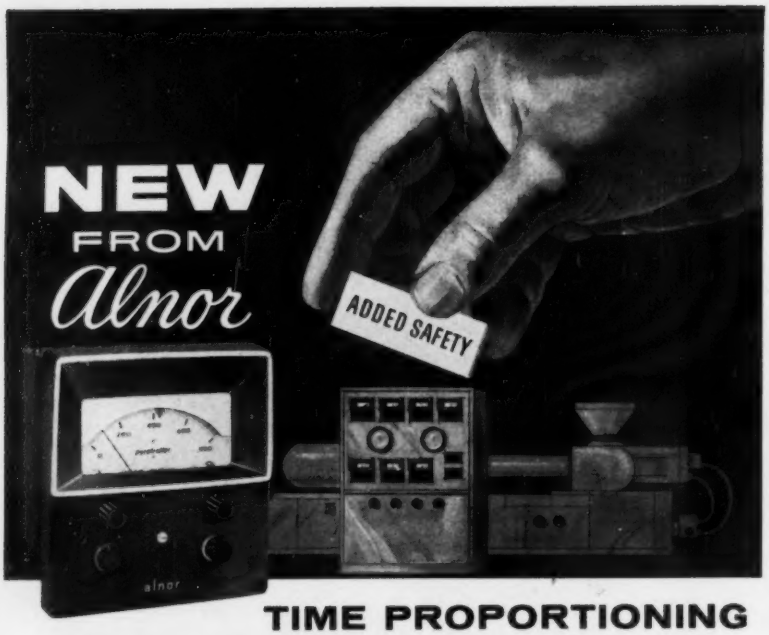

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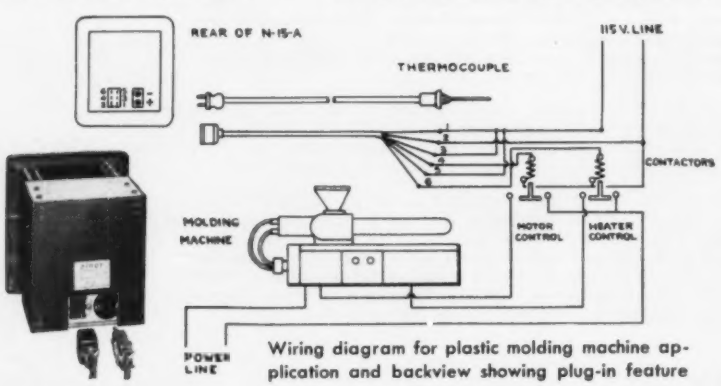

Wiring diagram for plastic molding machine application and backview showing plug-in feature

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Circle 1902 on Page 48-B

Metal Surfaces . . .

work hardening, and *(c)* a decrease in fracture strength.

An explanation of the Roscoe effect in terms of mobility of dislocations leans heavily on two concepts. The first, proposed by Fisher in 1952, is that a dislocation line emerging unpinned at the surface but pinned at some interior point can serve as a source of dislocations – a surface source. Since these dislocations should be activated at roughly half the stress required to activate interior sources, it follows that Fisher-type surface sources should be responsible for initial plastic flow.

The source's operation would be restricted or prevented if a surface film pins the end of a dislocation. Then the specimen must utilize other sources of dislocations – internal sources – which are "harder"; that is, they require a higher stress to activate them. The ultimate effect would be that the surface film would increase yield stress.

The second concept is that a surface film might be expected to prevent egress of dislocations from the crystal so that they become piled up beneath it. Since cracks can be formed by the piling up and coalescence of edge dislocations at stable obstacles, the rate of work hardening and fracture strength of a specimen should be affected. Considerable experimental evidence has confirmed these basic ideas on the influence of solid surface films.

There have been many explanations proposed for the Rebinder phenomenon. Earlier explanations by Rebinder and his co-workers – in terms of effects of microcracks and decrease in surface energy which accompanies adsorption – are not thought to be consistent with present-day ideas. Dr. Westwood and his associates, working with ionic crystals, are developing the hypothesis that the Rebinder effect involves preferred adsorption of polar molecules at points of emergence of crew dislocations.

Having demonstrated that polar molecules are adsorbed at dislocations, they are working to show that such chemisorption provides a drag on the end of a dislocation half-loop like an anchor, making the dislocation more difficult to move. Thus, contrary to Rebinder's early

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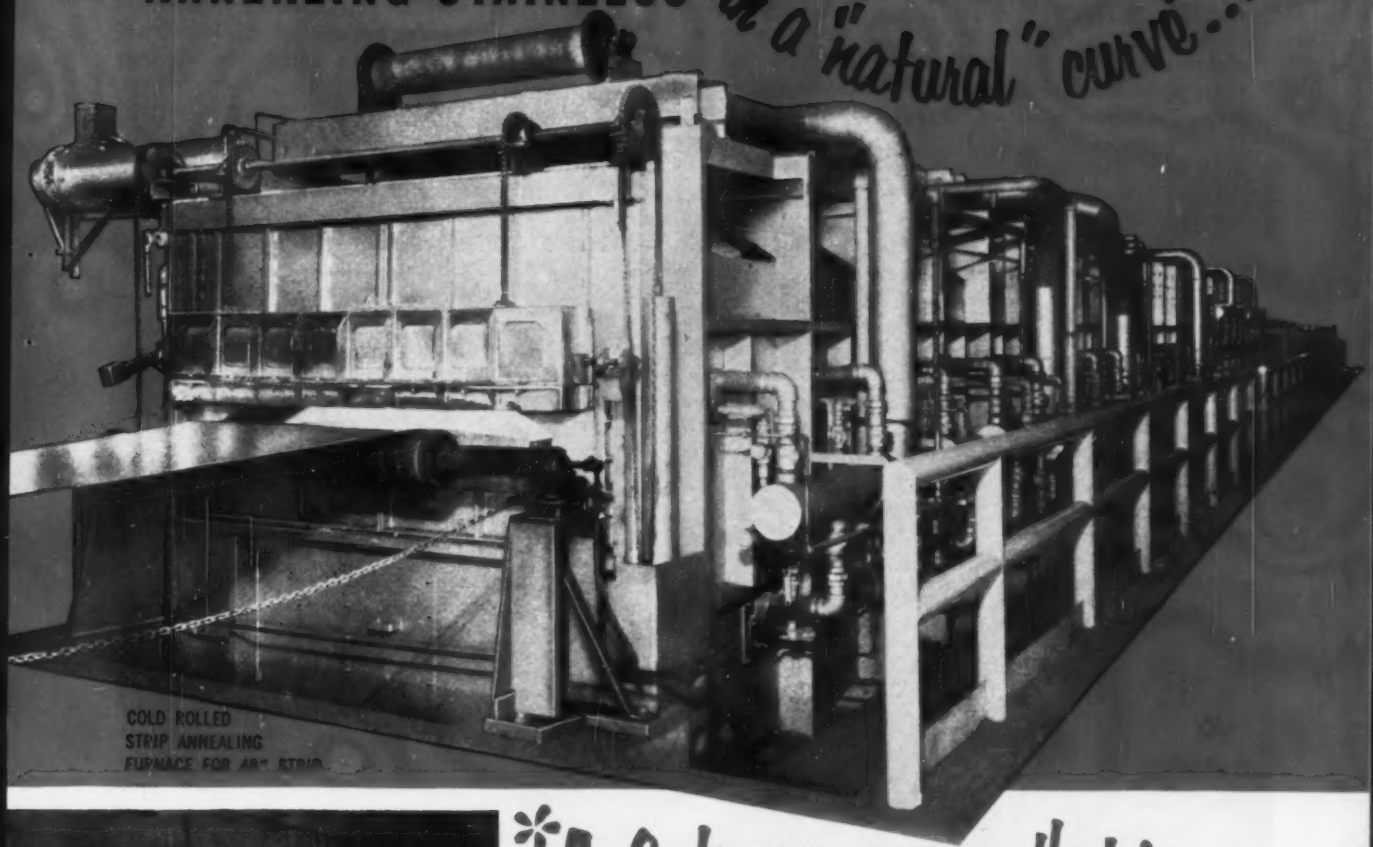

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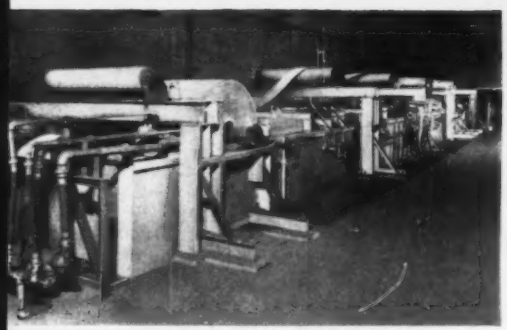
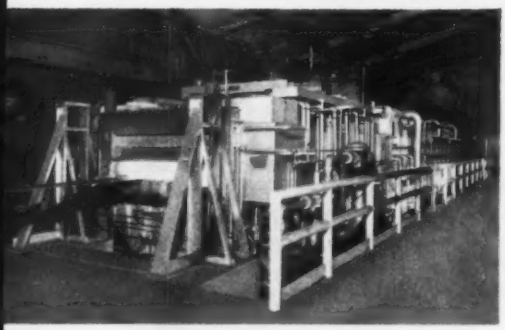


ABOVE: SALT DESCALING BATH. BELOW: HOT ROLLED STRIP LINE.



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Circle 1903 on Page 48-B

Metal Surfaces . . .

observations, they feel that yield stress of ionic crystals should in fact be increased, not decreased, in surface-active environments. This has now been observed experimentally (curve OHK, Fig. 4). An interesting point is that Western workers find that many of the Rebinder phenomena reported in Russian literature are virtually impossible to reproduce.

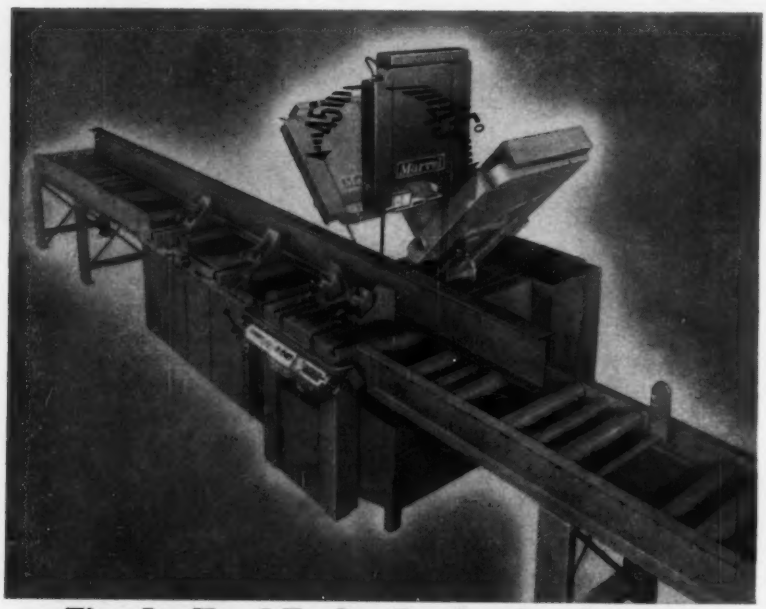
Internal Metallic Surfaces

While surfaces are thought of as being external to a body, bonding of one metal body to another occurs at the interfaces between them, and these interfaces constitute internal metallic surfaces:

Beginning with the assumption that every substance should adhere to every other substance with which it comes into intimate contact. F. N. Rhines (University of Florida) explored the question "Why is adherence often very weak?". It was proposed that a bond is always relatively strong and that strength of adherence is determined by mechanical properties of phases in contact and their geometric distribution in the joint. The bond interface is composed of a sequence of solid phase layers, each strongly adherent to its neighboring layers – bond strength being determined by resistance to rupture of the weakest phase in sequence. In simple tension or pure shear, soft materials assume the role of weakest layer; while in bending, brittle materials behave as weakest in the sequence.

Another concept, particularly applicable to bonds formed by diffusion layers, concerns the way that mechanical and chemical stability of a bond is fostered by minimizing its interfacial energy. Diffusion layers that form correspond to a consecutive sequence of tervariant (having three degrees of freedom) and higher-order equilibria traversing the phase diagram between terminal compositions of the diffusion couple. The diffusion layer sequence must represent a minimum free energy configuration for the components involved since a common observation is that this sequence of layers will thicken without change in number, kind, or sequence.

Such a sequence will remain stable as long as no new components are introduced into the system, and its properties will remain the same over a period of time. However, the introduction of a new component may require revision of the phase-layer sequence. These principles may be used as practical guides to the extent that they indicate what kinds of changes would have to be made in the structure of a bond to alter its mechanical properties in a specific way.



Tips Its Head To Cut Production Corners

Sawing 45° miters in any kind of material has always been a simple task for MARVEL Saws, but moving the work up automatically and making consecutive cuts on an angle was a problem, especially when the work was long and cumbersome.

This triple exposure photograph of a new MARVEL No. 81A All Hydraulic Heavy Duty Automatic Bar Feed Band Saw, illustrates how the upright head or column can be tipped 45° either right or left of vertical to make angle or miter cuts. The work is held stationary while the column, which carries the blade, is fed forward, meeting the work squarely to insure accurate cutting. After the cut is completed, the work is automatically moved up and measured, and another cut made.

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MARVEL Metal Cutting SAWS

Circle 1904 on Page 48-B

Refractory Metals—Their Melting and Casting

Though fairly large ingots of molybdenum, columbium, tantalum, and tungsten can be produced, commercial processes for making shaped castings of these metals are still in the future.

IN SUMMARIZING THE PRESENT state of the art of melting and casting of molybdenum, columbium, tantalum, and tungsten, this report placed particular emphasis on the status of producing shaped castings of these four refractory metals. Three major processes are used for making forms of refractory metals: powder metallurgy, vacuum arc melting, and electron-beam melting. In the powder metallurgy process, ingots (which can weigh several hundred pounds) are produced by

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The colorful Tool Steel STEELECTOR Booklet gives complete details of the program, explains the Data Stock Lists, and includes the three STEELECTOR Cards. Ask your Allegheny Ludlum sales representative for your copy, or write: ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MP-11.***

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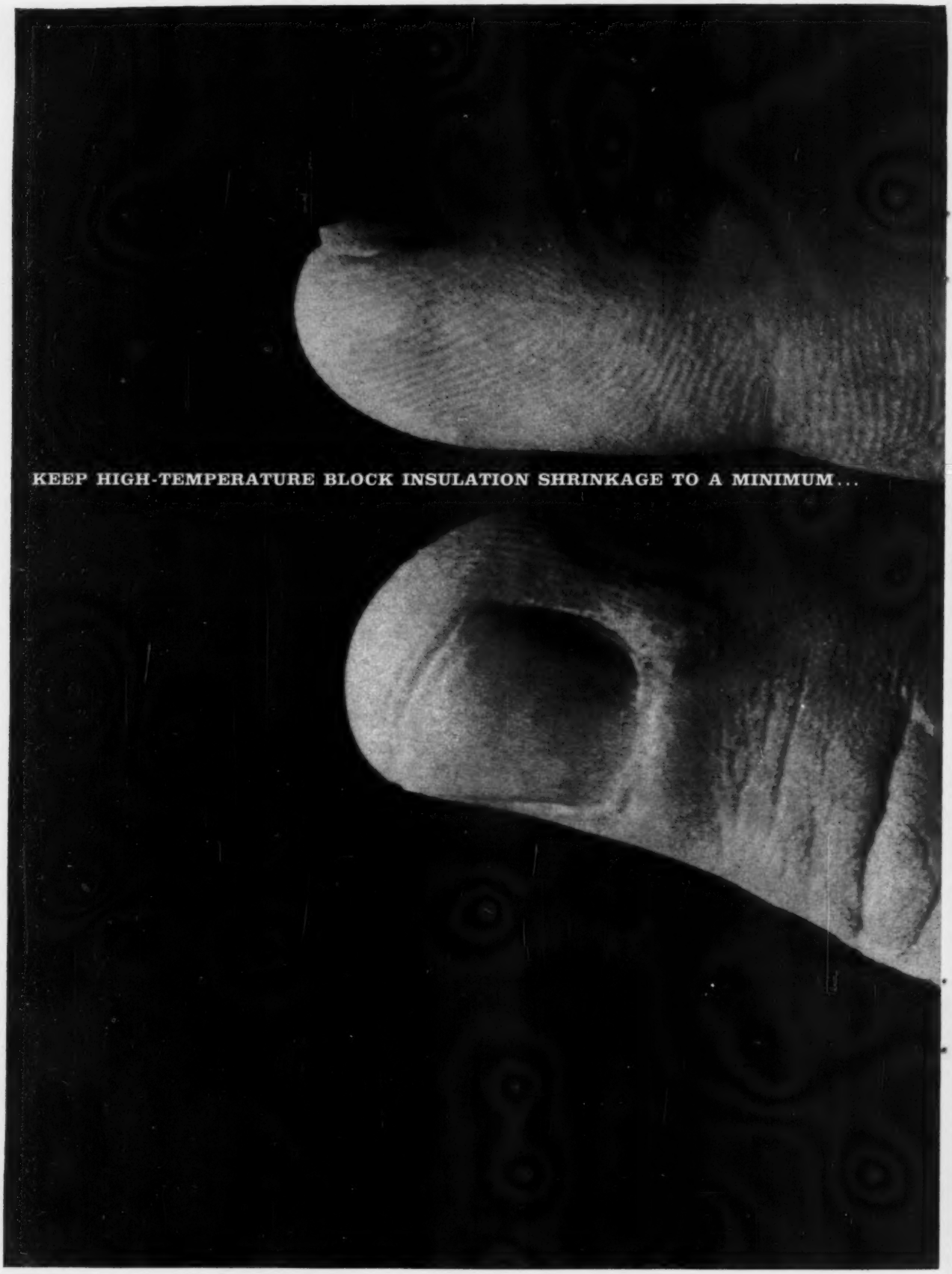
Circle 1905 on Page 48-B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Circle 1906 on Page 48-B

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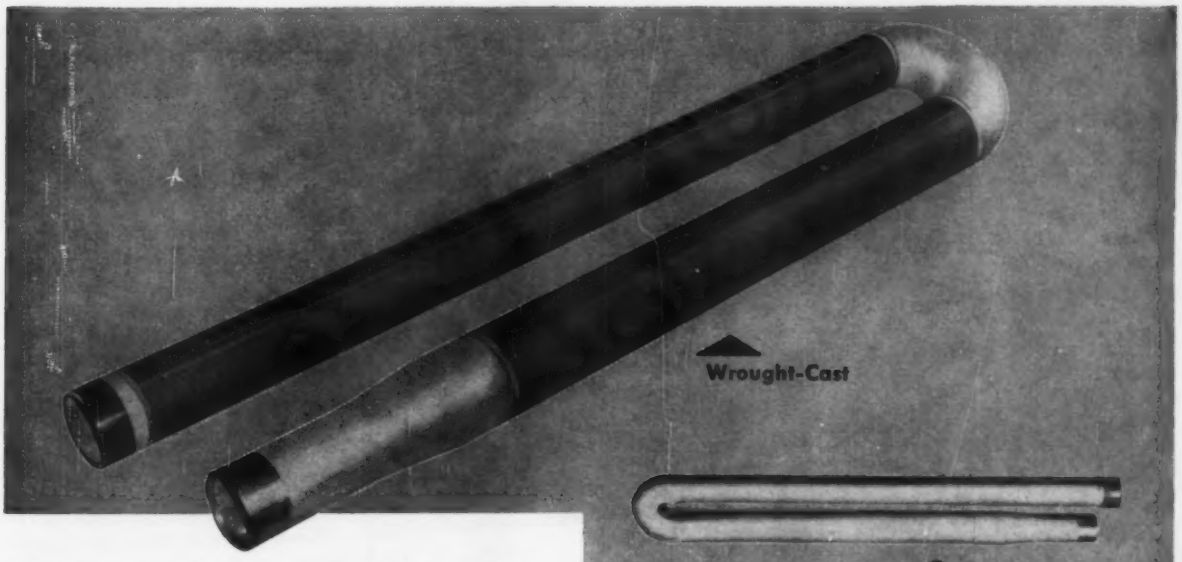
Circle 1907 on Page 48-E

Refractory Metals . . .

hydrostatic pressing appropriately prepared powders in a plastic container; the compacts are then sintered. Refractory metals are also vacuum remelted by the consumable-electrode process. Unlike ingots produced by powder metallurgy techniques, arc-melted ingots, which can be up to 24 in. in diameter, characteristically have a large grain size with insoluble impurities concentrated at the grain boundaries. As a consequence, these ingots are generally more difficult to work than ingots made by powder metallurgy methods. Very pure ingots can also be made by the electron-beam drip melting process. This relatively new method employs a high vacuum in which an electron beam is maintained. Very high temperatures are produced in the system. A beam of electrons is emitted from each of two resistance-heated tungsten filaments or "electron guns". When operating, the upper gun is focused on the tip of a metal bar which then melts and drips into a cold copper mold. The top layer of the ingot is kept molten by the electrons emitted from the lower gun. As for the ingot mold, it is shallow and open at the bottom so that the ingot can be extracted from the mold as it freezes. The rate is such as to maintain the top of the molten pool at a constant level.

Columbium and tantalum are particularly well suited to electron-beam melting. Almost all of the impurities are removed by evaporation during the melting cycle, a feature of real importance since the maintenance of extremely high purity is the key to the production of refractory metals with good ductility.

In refractory metal applications for space vehicles, molybdenum has a dominant position because of its outstanding properties in the 2000 to 2500° F. range. However, molybdenum has two major shortcomings, brittleness at low temperature and poor oxidation resistance at high temperatures. Brittleness may be largely overcome by purification. Resistance to oxidation has also been improved by the development of coatings that are protective at temperatures up to 2500° F.



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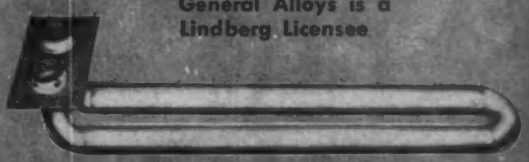

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Circle 1908 on Page 48-B

Marshall Furnaces at Union Carbide

VACUUM TESTS TO 4000°F

Marshall Furnaces, specially designed for Union Carbide Metals Company, Niagara Falls, N.Y., make possible vacuum tests at temperatures to 4000° F. In tensile machine (right), furnace creates temperatures to 4000° F. at pressures less than 0.2 micron to test tungsten, tantalum, and columbium base alloys. Dynamic Moduli Furnace (above) produces up to 4000° F. for vacuum dynamic moduli tests.

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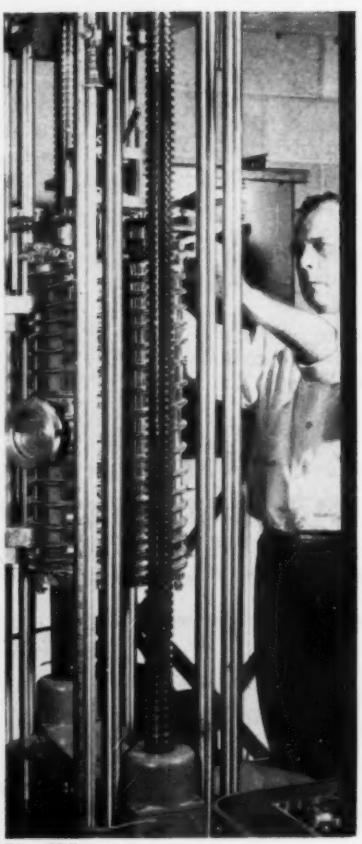

MARSHALL FURNACES

Circle 1909 on Page 48-B

Refractory Metals . . .

Progress in Casting Techniques

Significant progress has been reported in research aimed at the production of shaped castings from all four of these refractory metals. Molybdenum has been cast in static and centrifugal molds using the so-called skull-melting process. Four different experimental designs of castings have been produced: (*a*) a fluidity test runner with a diameter of 7/16 in., (*b*) a plate measuring 1 by 2 by 8 in., (*c*) a pipe tee, and (*d*) a centrifugally cast cylindrical tube 4½ in. outside diameter, by 8 in. long with a wall thickness of 1 in.

However, more research is needed before static castings of molybdenum can be produced with acceptable surface appearances and satisfactory internal soundnesses, even though centrifugal castings of molybdenum can be made dense and sound at the present time. As a criterion, good castings are expected to have mechanical and physical properties comparable to those of sections taken from arc-melted ingots.

What is believed to be the first columbium casting was recently reported. An experimental tube blank, 10 in. long with an outside diameter of 4 in. and a wall thickness of 1⅜ in., was centrifugally cast. The metal was arc-melted in a skull furnace under vacuum, and cast in a machined graphite mold.

Several attempts to cast tantalum in machined graphite molds have been reported. Five heats were successfully cast in the form of fluidity spirals ½ in. in diameter, 12 in. being the maximum length achieved. These results indicate that shaped castings of both columbium and tantalum are feasible. However, no commercial casting processes have been placed in operation to date. Additional research is required, particularly in the areas of gating and risering as well as in alloy development.

Considerable progress in the casting of tungsten has been reported recently. Although the quality of tungsten castings is not as good as that obtained with tantalum and columbium, it is hoped that a good technique will soon be developed.

(Continued on p. 156)

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers

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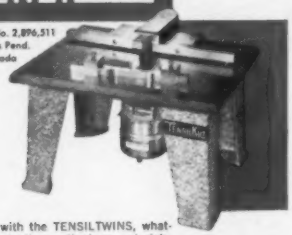

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Circle 32 on Page 48-B

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Circle 33 on Page 48-B

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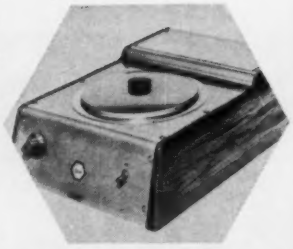

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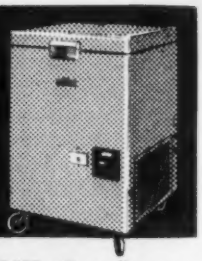

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Circle 43 on Page 48-B

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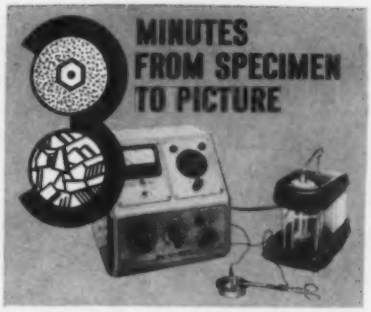
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

Circle 45 on Page 48-B



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WILLIAM J. HACKER & CO., INC.
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Circle 46 on Page 48-B

BRINELL and VICKERS TESTS *without* **microscopic measurements**

the Gries REFLEX hardness tester covers the ENTIRE range of hardness from the softest to the very hardest. It yields standard test data by Zeiss automatic projection system—the ultimate hardness tester for research and routine inspection.

Ask for bulletin No. A-14

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

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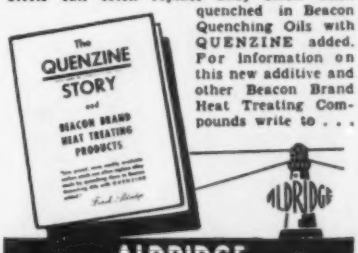
FREE

***the* QUENZINE STORY**

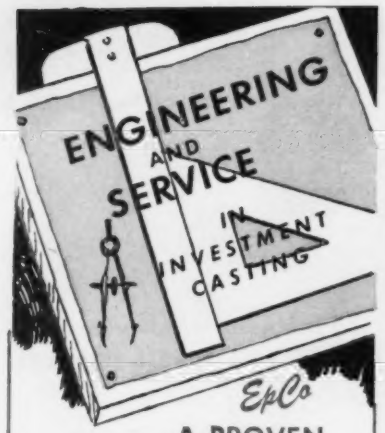
Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



ALDRIDGE

ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio

Circle 48 on Page 48-B



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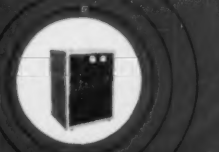

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Circle 52 on Page 48-B

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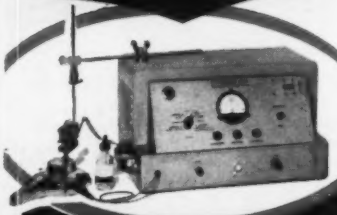

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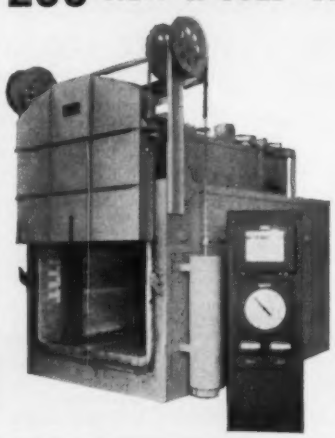

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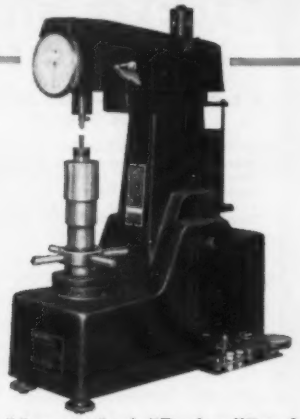
Circle 50 on Page 48-B

Wilson "Rockwell" TWINTESTER



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WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division

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ACCO

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Instrument panels of Magic Chef ranges are framed in the magic metal—aluminum . . . extruded, fabricated and anodized by GENERAL EXTRUSIONS, INC. This is another example of a leading manufacturer solving his requirements for durability, beauty and utility with G.E.I.'s uniform quality and unfailing delivery. Discuss your extruded aluminum needs—one part or a million—with G.E.I.

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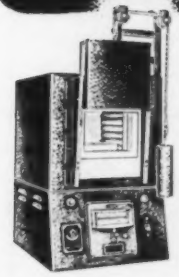
Consult your classified phone book under Aluminum Products

Circle 57 on Page 48-B

HUPPERT ELECTRIC FURNACES AND OVENS
for Laboratory and Plant



*For 2300°F. add $95.00 to No. 11 and No. 12, and $105.00 to No. 12A. No. 12A can be furnished for 3 phase at no additional cost. For floor model add $52.00 to above prices. No. 869 standardly supplied for 2200°F.

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- Range: 300°F. to 2000°F.
- High temperature, heavy-duty Kanthal elements
- Multi-insulation
- Counter-weighted, tight-sealing door
- Operational pilot light
- Shipped ready to operate

Model No.	Inside Dimensions			KW	Prices 220 Volt Single Phase	
	Wide	High	Deep		With Huppert Input Controller	With Electronic Prop. Controller
869	8"	6"	9"	4	$296.00	$480.00
11*	8"	6"	12"	4	306.00	518.00
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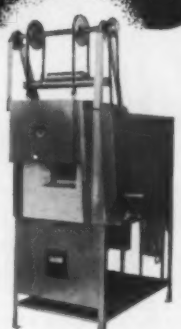

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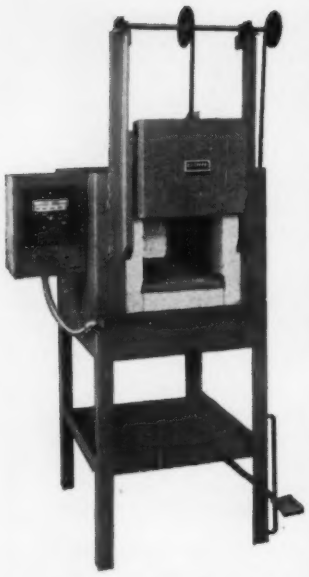
K. H. HUPPERT CO.
Manufacturers of Electric Furnaces and Ovens For A Quarter Century
6844 Cottage Grove Ave., Chicago 37, Illinois

Request new catalog on furnaces, ovens, data, prices.

Circle 58 on Page 48-B

LUCIFER "SPACE-SAVER" COMBINATION HEAT TREATING FURNACES



Two series (8012 and 8008) of "space-saver" combination heat treating furnaces are produced by Lucifer Furnaces, Inc. Hardening, drawing or preheating, and quenching operations can be performed with one furnace. Each furnace has separate controls permitting independent operation of each unit. The 8012 series chambers operate at 2300, 2000 and 1250° F.; while the 8008 series chambers reach 2300, 2000, and 800° F. The furnaces operate on standard line voltage . . . no transformer necessary. Twenty standard low-cost models are available and each is a complete unit . . . just connect to power supply.

For information about the "space-savers", our complete line, or free engineering advice, call on . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Pennsylvania
Diamond 3-0411

Circle 59 on Page 48-B

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
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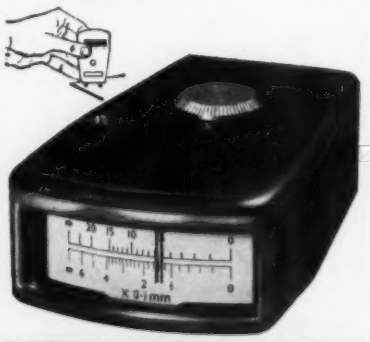
More than 10,000 in use:



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Circle 62 on Page 48-B

Rockwell-scaled
HARDNESS TESTER

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Test Block accurate instrument only $39.50 complete

A steel ball of exact weight and hardness is dropped from an exact height, insuring a precise reading in Rockwell C scale. Ideal for spot or production checking. Used in many of the finest plants and shops. Get "on-the-job" readings *anywhere* with dependable accuracy. Easy to use, easy to read. No moving parts to get out of adjustment, even if the instrument is dropped. A one-year warranty protects against defects in materials and workmanship.

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Detroit Hardness Tester Co.
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Circle 63 on Page 48-B

A User of the New METALS HANDBOOK *Says—*

"Last week my Metals Handbook provided specific information on corrosion of copper alloys that made it worth many times its cost. I expect to order another copy so that I will have one at my home and another at my office."

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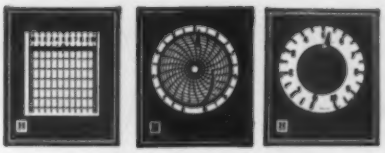
Second copies are $30.00 each (plus $2.00 postage if you are located overseas). Write for your copy to:

American Society for Metals
Metals Park, Ohio

THE ALL-NEW *ElectroniK 17*

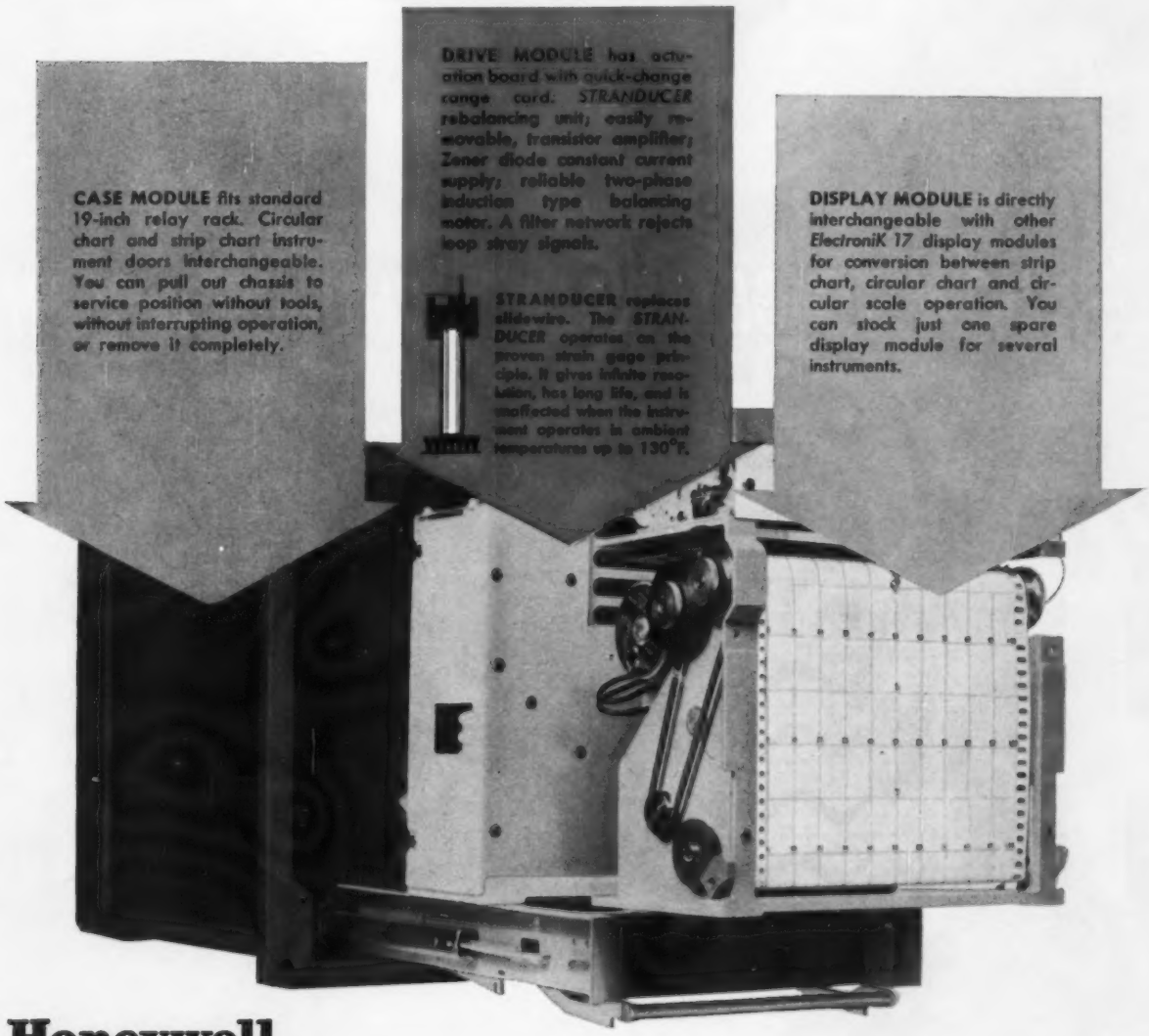


. . easiest and least expensive of all potentiometers to operate, convert and maintain

Here, for the first time in a small-case potentiometer, you get all the operating and maintenance advantages of modular design, plus accuracy within ±0.25%, a revolutionary new rebalancing element, and many other time-saving, cost-cutting, performance-improving features.

Three basic modules—case, display and drive—make up the *ElectroniK 17*. The case fits standard 19-inch relay racks. Attach a carrying handle and the instrument is portable. Pull out the chassis to the service position without tools, without interrupting operation, or remove it completely. Vary chart speeds ½ or 2 times basic speed by replacing quick-change drive gears. Standard chart speeds 1, 2, 6, 10, or 60 inches per hour. Plug into the instrument up to 8 contact control units for widely varied control possibilities. *ElectroniK 17* instruments are available as strip or circular chart recorders, or circular scale indicators.

For the eye-opening details on great new *ElectroniK 17* instruments, call your nearby Honeywell field engineer, or write MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.


CASE MODULE fits standard 19-inch relay rack. Circular chart and strip chart instrument doors interchangeable. You can pull out chassis to service position without tools, without interrupting operation, or remove it completely.
DRIVE MODULE has actuation board with quick-change range card. STRANDUCER rebalancing unit; easily removable, transistor amplifier; Zener diode constant current supply; reliable two-phase induction type balancing motor. A filter network rejects loop stray signals.
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DISPLAY MODULE is directly interchangeable with other ElectroniK 17 display modules for conversion between strip chart, circular chart and circular scale operation. You can stock just one spare display module for several instruments.

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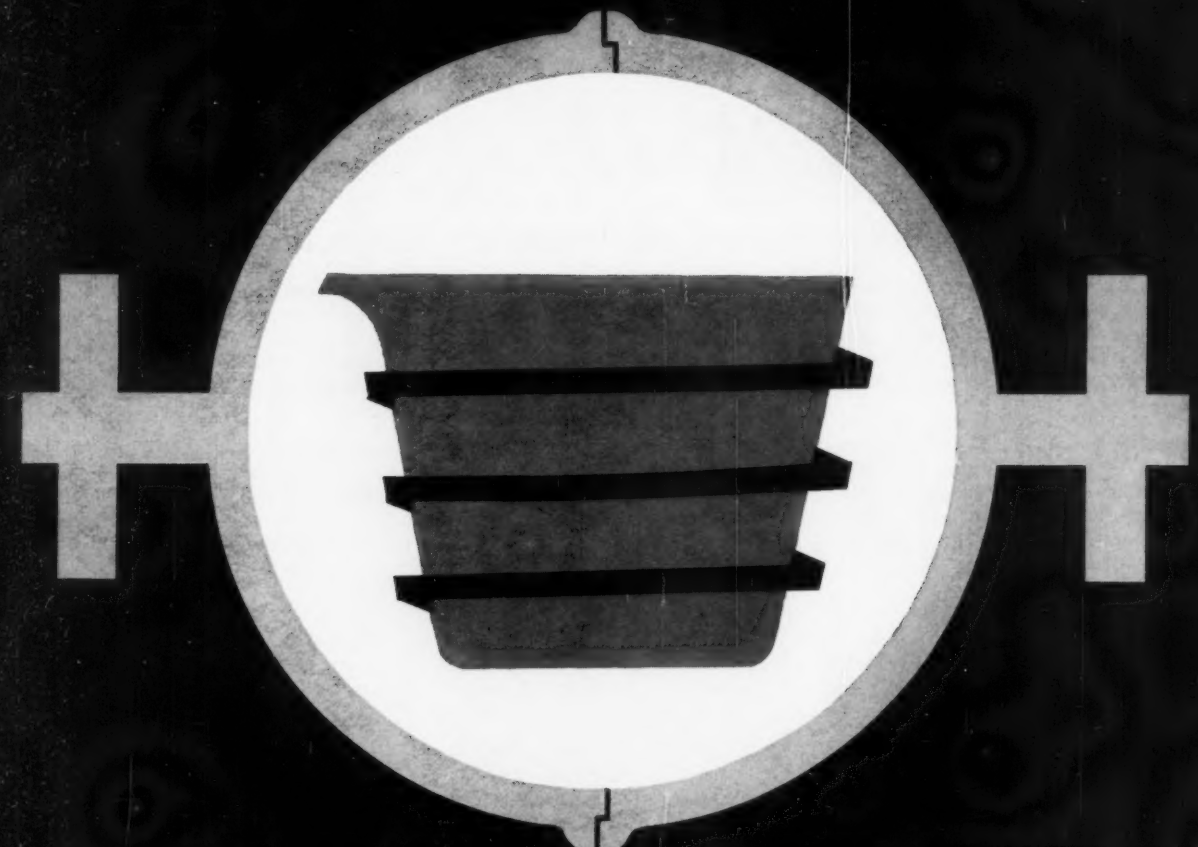
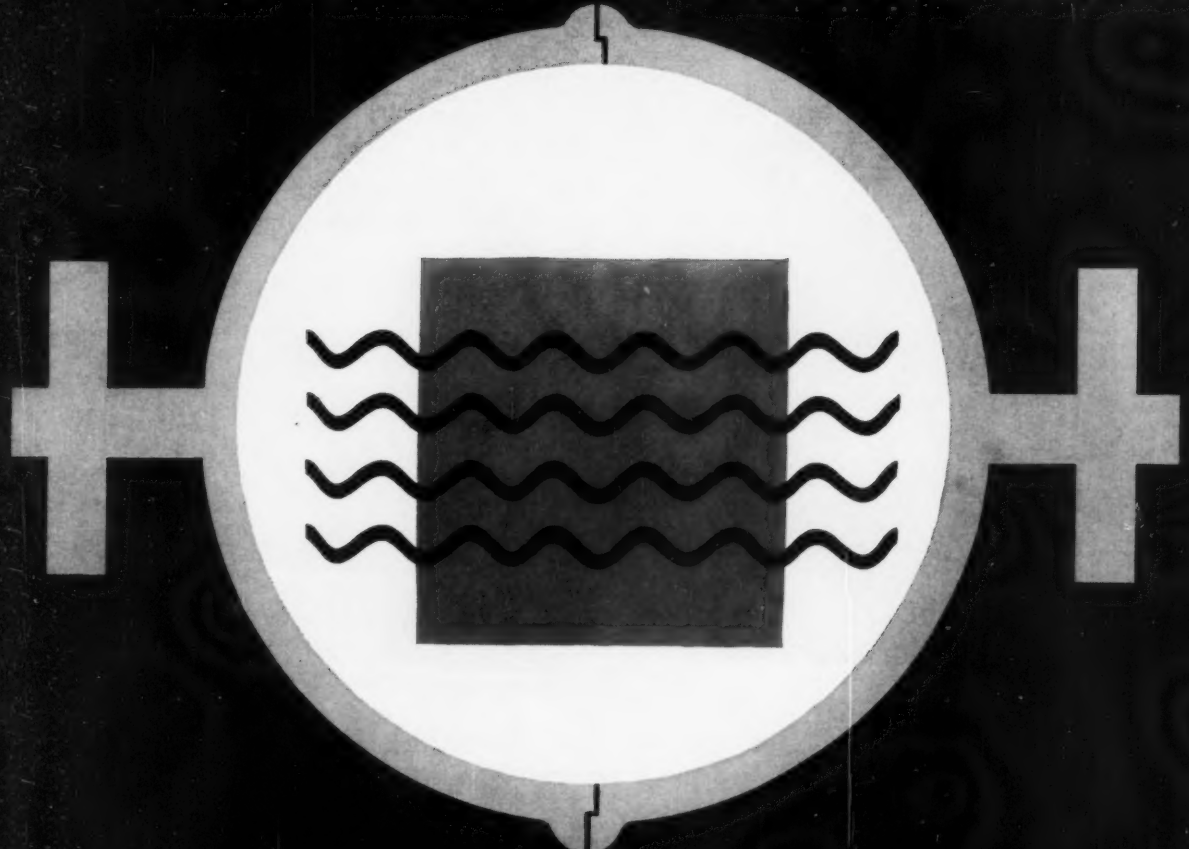


HOW TO GET YOUR VACUUM'S WORTH



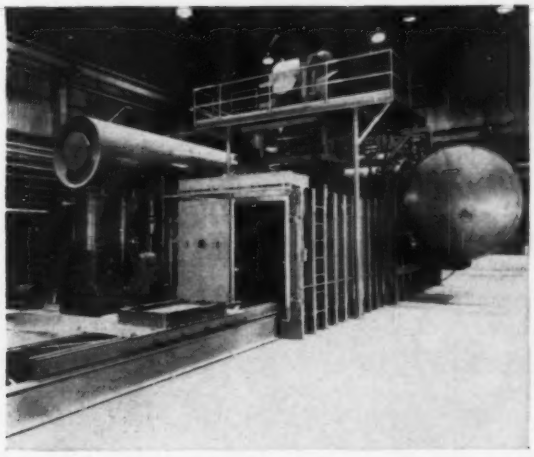
The operating efficiency of the vacuum furnaces you buy depends on how well the vacuum system is integrated with the heating function. With Stokes resistance and induction furnaces, you get a thoroughly integrated system that gives you top performance in both areas.

By combining more than *forty years* of experience in equipment manufacturing with the latest vacuum and heating techniques, Stokes has created a line of furnaces that delivers the ultimate in balanced performance to meet today's highest standards of product quality and uniformity.

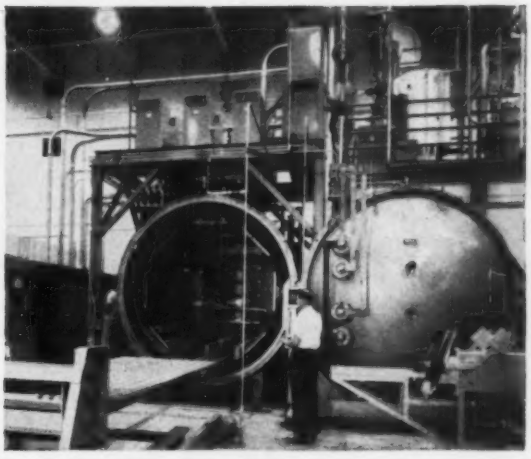
These furnaces handle products ranging from precision castings to nuclear materials and fabricated assemblies. Stokes standard furnace equipment is available for melting, sintering, brazing, degassing and heat treating. Melting furnaces are offered in sizes from five to five thousand pounds capacity for either batch or semicontinuous operation. Resistance furnaces cover all temperature ranges up to 2500°C.

Let Stokes extensive vacuum metallurgical experience and facilities *work for you.* Stokes Engineering Advisory Service can help in selecting the most efficient vacuum system for your requirements . . . from single units for research and development to complete turnkey installations. Get the vacuum help you need by writing or calling today. Vacuum Metallurgical Division, F. J. Stokes Corporation, 5500 Tabor Road, Philadelphia 20, Pa. *In England:* Vacuum Industrial Applications (VIA), Wishaw, Scotland. *On the Continent:* Societe Generale d'Applications Electro-Thermique, Boulgne (Paris), France.

in resistance and induction vacuum furnaces



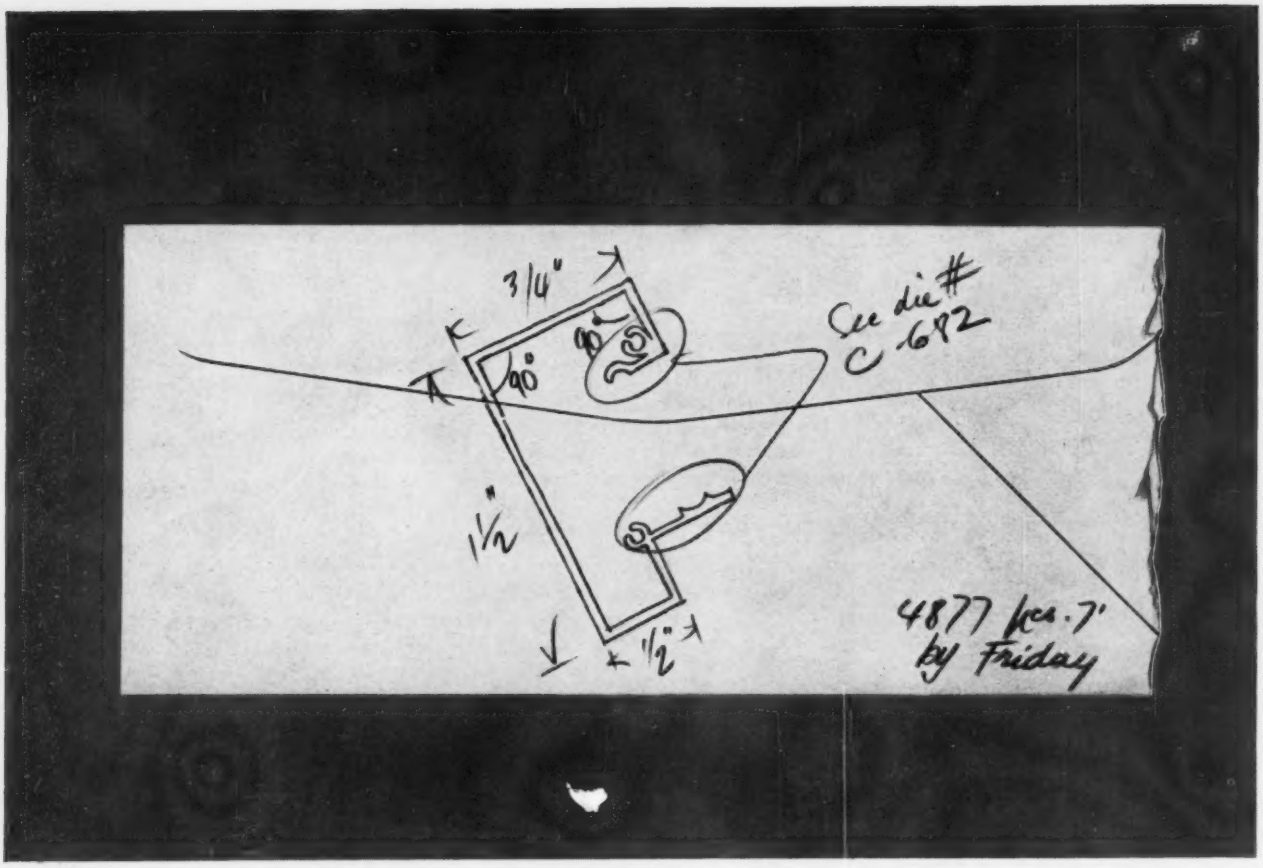
With a rated capacity of 4,000 pounds, this special-purpose induction vacuum furnace ranks as one of the largest ever built. Designed and built for the Sierra Metals Corporation, the furnace is currently producing nickel- and cobalt-base jet engine alloys. The vacuum pumping system is capable of developing unusually high volumetric capacity at extremely low pressures in the range of one micron.



The Astronautics Division of General Dynamics Corporation puts the world's largest cold-wall vacuum furnace into production. Furnished by Stokes as a complete turnkey installation, the facility is currently being used in production brazing and heat treating of large, stainless steel assemblies.

STOKES INTERNATIONAL: PHILADELPHIA • TORONTO • LONDON **STOKES**

Circle 1911 on Page 48-E



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Circle 1912 on Page 48-B

footenotes on the art of producing higher-quality steels

SUBJECT:

aluminum

at work in steel

Aluminum serves three purposes in ferrous metallurgy. It is (1) an alloying element, (2) a deoxidizer, (3) a grain-refining agent.

Aluminum an Aid in Creating Wear-resistant Steels

As an alloy of iron, aluminum has been put to good use in heat-resisting alloys and permanent magnet alloys. The largest single use, however, is in nitriding steels. The nitriding process is one in which aluminum bearing steels are held for a long time in ammonia at an elevated temperature. The precipitation hardening which occurs with the dispersion of aluminum nitrides at the surface, gives these steels a hard, wear-resistant case.

Aluminum a Versatile Control from Heat to Ingot

As a deoxidizing agent, aluminum is used in various ways in steel. In rim, capped or semi-killed steels, aluminum can be used to partially deoxidize heats in the ladle, thus limiting the evolution of gases, or it can be used to stop reactions in the ingot. In the latter case, the degree of usage is varied. Some ingots are chemically capped by an aluminum addition. Other ingots may be aluminum treated only when it is necessary to control bleeding. Even when steels are fully killed with silicon, aluminum is sometimes added in the ladle to insure complete deoxidation.

Aluminum Refines Grain, Reduces Strain Sensitivity

Steels which require aluminum for grain control fall into two main categories: (1) steels in which aluminum is added in conjunction with another deoxidizer, generally silicon; (2) steels in which aluminum is the only deoxidizer used.

In the first instance, only enough aluminum is added to refine the grain and obtain the desired physical properties of a fine-grain steel.

The second usage stems from the marked effect which aluminum has in reducing the strain sensitivity and strain aging of low carbon steels. As might be expected, the primary use for these steels is in sheet applications where the metal undergoes severe deformation.

Foote Manganese-Aluminum Alloys Produce Better Surface, Cleaner Steels

Foote offers a series of manganese-aluminum alloys for steel-making. These alloys provide a high density means of adding aluminum to steel. In the alloyed form, greater dispersion of aluminum is possible. An added bonus is that this reduces the tendency towards "tapering off" of aluminum analysis on the last ingots. Better surface and cleaner steels are reported with use of Foote alloys.

For further information on Foote manganese-aluminum alloys, write Technical Literature Department, Foote Mineral Company, 424 Eighteen West Chelten Ave., Phila. 44, Pa.

FOOTE MINERAL COMPANY

Circle 1913 on Page 48-B

Refractory Metals . . .

According to one report, tungsten has been cast to the rough contour of a rocket nozzle through use of the skull-melting process. For this nozzle, approximately 100 lb. of molten tungsten was poured into a machined graphite mold. Although some of the molds were used for as many as eight castings, indications were that they could be used several times more before discarding. Carbon was absorbed and diffused into the surface of the castings (with or without the use of mold coatings) on the order of 150 mils.

Refractory metals have also been produced by a thermit reaction in a recently patented apparatus capable of withstanding very high pressures and temperatures. Although most of the development work was performed with tungsten, similar work has also been done with molybdenum, columbium and tantalum. As described in the patent, the process is conducted in a cylindrical steel furnace, which is protected by the inner wall of replaceable sleeve. This sleeve is made of an expendable refractory material. The charge was composed of a thermit mixture — fine aluminum powder mixed with tungsten oxide. In operation, the base of the furnace is placed in a vertical position so that the charge contacts the metal base. A metal piston then touches the top of the charge, and action starts when an electric current flares from the furnace wall to the mixture. The application of the piston subjects the mixture to a high pressure at the time that the reaction develops a high temperature. Since the reaction is so violent that it approaches detonation, 10 to 15 lb. (of tungsten) is the maximum that can be produced with safety. Purity ranges between 99.0 and 99.6%, and the time cycle is about 20 min.

Summing Up

Problems inherent in melting and casting the refractory metals are well recognized and are being investigated. In fact, efforts to surmount these difficulties surpass the present-day demands for ingots produced by these processes. Improvements would undoubtedly occur more rapidly if a substantial increase in application for refractory metals

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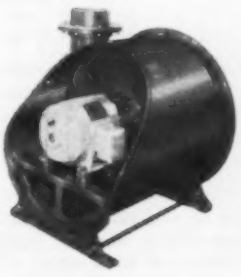

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Circle 1914 on Page 48-B

Refractory Metals . . .

could be foreseen. It appears unlikely that a large demand will develop in the immediate future for shaped castings of molybdenum, columbium or tantalum. Although most companies engaged in space programs are generally reluctant to use them, indications are that some would seriously consider refractory metal castings if they were available.

In this connection, there appears to be an immediate need in the space program for a commercial casting process for tungsten. Even if only rough castings could be produced for rocket nozzles, they would require substantially less metal removal by machining. Furthermore, the cracks and residual stresses that are induced in parts machined from large ingots would be lessened.

In conclusion, it is pointed out that the production of ingots of refractory metals is much more advanced technically than is the production of shaped castings. Satisfactory methods for commercial production of shaped castings of the refractory metals are at the present time almost nonexistent. The major drawback is the inability of known melting processes to superheat a large enough quantity of metal. Increasing the degree of superheat will provide for a greater degree of purification and increased fluidity. This, in turn, will act to alleviate gating and risering problems in the production of refractory metal castings.

W. W. AUSTIN

Digest of "Melting and Casting of the Refractory Metals Molybdenum, Columbium, Tantalum, and Tungsten", by W. H. Johnson, Defense Metals Information Center Report 139, Nov. 18, 1960, Battelle Memorial Institute, Columbus, Ohio.

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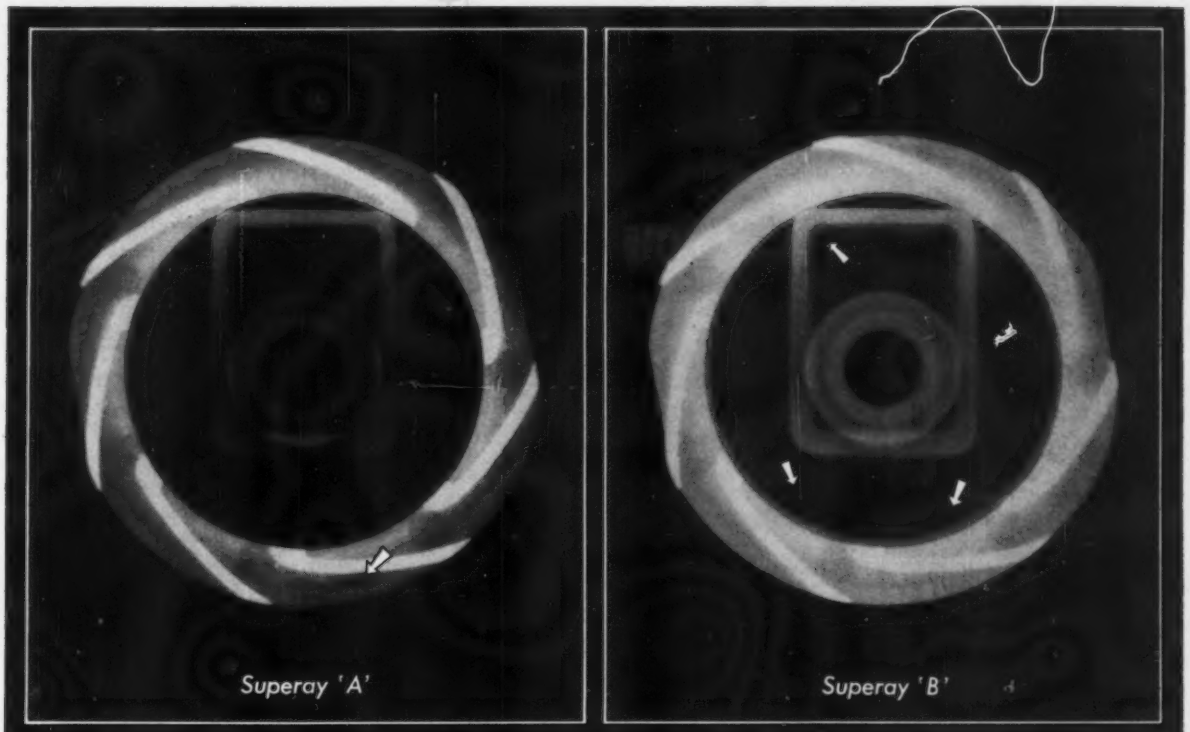
How Al and N Affect the Fracture of Steel Castings

"Rock candy" fracture due to critical amounts of aluminum and nitrogen can be controlled by special heating practices or the use of titanium and zirconium for deoxidizing.

A PECULIAR FORM of fracture, known as "rock candy" or "intergranular" fracture and characterized by large, smooth facets, is occasionally found in carbon and low-alloy steel castings. Actually, the fracture is not strictly intergranular. This type of fracture occurs around the boundaries of the prior delta or austenitic grains. The present investigation was carried out to examine the role played by aluminum nitride.

For the experiments, steels were made (in induction furnaces) of materials containing different nitrogen contents, and were cast into green sand molds. Sections from the castings were oil quenched from 900° C., (1650° F.), tempered at 650° C. (1200° F.) for 1 hr., and water quenched to avoid temper brittleness. They were then notched, and broken by slow bending in a hydraulic testing machine. The total nitrogen, acid-soluble nitrogen, aluminum nitride, and acid-



The two radiographs of a multiple thickness aluminum casting (minimum to maximum thickness—1 inch) were exposed simultaneously on Superay® 'A' and Superay 'B' X-ray film in a Sandwich Pak. Defects in thinner portions were recorded on Superay 'B' (the slower film). Shrinkage and inclusions in thicker sections were recorded on the faster film (Superay 'A'). Both films developed for 6 minutes in Ansco Liquadol at 68°.

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Circle 1917 on Page 48-B

Fracture . . .

soluble aluminum contents were separately determined.

Preliminary experiments with a low-alloy composition showed that a form of intergranular fracture could be produced by treatment with aluminum, providing that a slow cooling rate was achieved after solidification, or the castings were held in the range 900 to 1000° C. (1650 to 1830° F.). The fracture was associated with a grain boundary precipitate of aluminum nitride.

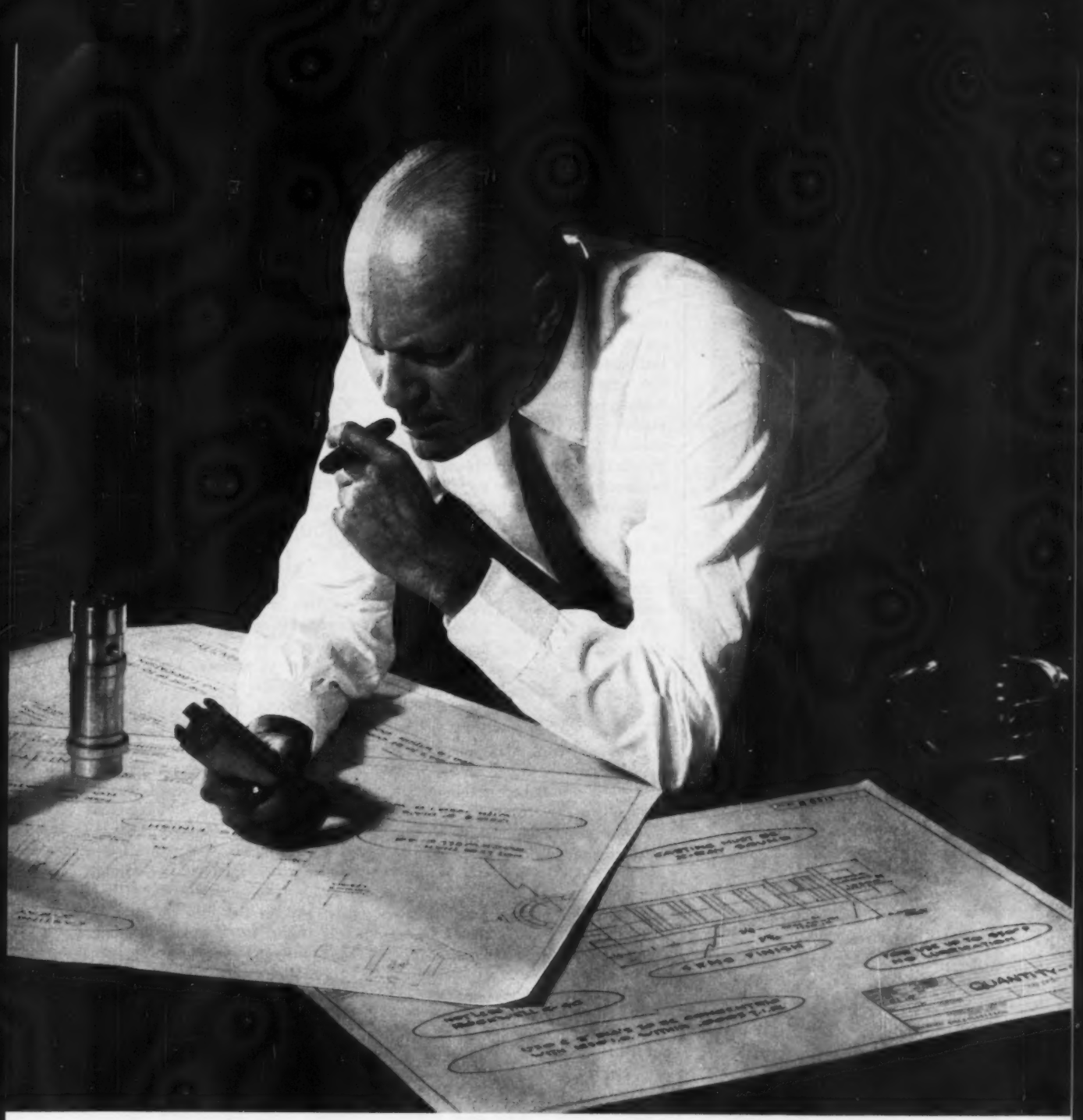
Effect of Al/N Ratio

A series of tests was made on an En 100 composition, using electrolytic iron, plain carbon steel and Armco iron as base materials, with various aluminum additions. It was found that 100% intergranular fracture could be obtained with low acid-soluble nitrogen (0.005%) and high aluminum addition, or with high total nitrogen (0.015%) and relatively little aluminum. With 80% intergranular fracture, only faint traces of grain-boundary precipitate were observed, but as the aluminum nitride content increased, the precipitate changed from rounded particles to needles growing out from the grain boundary. The precipitate became coarser with increasing aluminum content, until at 0.8% Al it ceased to occur at the grain boundaries but was uniformly distributed within the grains. Under these conditions (0.016% N), no intergranular fracture was observed.

Effect of Ti and Zr

Since titanium and zirconium nitrides are more stable than aluminum nitride, the effect of these elements was studied in casts of Ni-Cr steel. With 0.012% N and 0.14% Al, intergranular fracture was obtained as before. The addition of 0.08% Ti, however, prevented this type of fracture, without adversely affecting the mechanical properties, even though a grain-boundary film (presumed to be Ti-Mn-Fe sulfide) was present.

The results obtained with additions of 40% Zr silicon alloy were less encouraging. Without aluminum, the fractures were not intergranular, but when aluminum was present, Si-Zr additions up to 4 lb. per ton were completely ineffective in preventing intergranular fracture.



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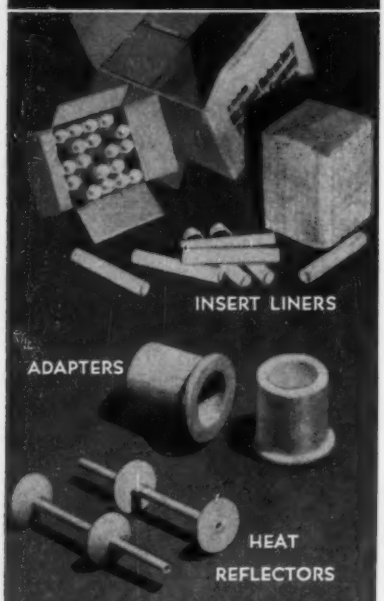

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Fracture . . .

Effect of Heat Treatment

Aluminum nitride can be taken into solution in austenite by heating in the range 1100 to 1250° C. (2000 to 2300° F.), and retained in solution by quenching. The effect of this treatment, followed by tempering at 650° C. (1200° F.), was investigated with a cast which gave 80% intergranular fracture after holding in the range 900 to 950° C. (1650 to 1740° F.). The results showed that the amount of intergranular fracture could be reduced by heating to 1100 to 1200° C. (2000 to 2200° F.), but could only be completely removed by heating at 1250° C. (2300° F.) for longer than 2 hr. Subsequent experiments showed that intergranular fracture reappeared on cooling below about 1150° C. (2100° F.), although it then occurred at the interfaces of the austenite grains established by the high temperature heat-treatment.

Commercial Castings

Examination of some commercial castings showing intergranular fracture gave a number of interesting results. In two instances, the fracture was considered not to be due to aluminum nitride alone. In one of these, a C-Mn steel, intergranular fracture was associated with grain-boundary films of ferrite, and did not occur when the samples were quenched and tempered. In the other, a 4% Ni-Cr steel, the intergranular weakness was removed at 1250° C. and could not be made to reappear by holding at low temperatures or by slow cooling. Furthermore, a series of high temperature heat treatments carried out on samples from a 6-in. thick casting of armor plate showed almost exactly the same response as did the experimental cast.

Conclusions

Aluminum nitride can produce intergranular fracture in steel castings, but this defect in aluminum-killed steels can be minimized by keeping nitrogen low, by restricting aluminum additions to the minimum required for complete deoxidation and by a high cooling rate after solidification. Intergranular fracture can be avoided by deoxidizing with titanium or zirconium, or with titanium in combination with aluminum. When this type of fracture is due to aluminum nitride, it can be removed by heating at 1250° C., and will reappear on slow cooling below 1150° C.; this constitutes a useful test for aluminum nitride embrittlement.

R. C. A. THURSTON

Digest of "Effect of Al and N on the Occurrence of Intergranular Fracture in Steel Castings", by B. C. Woodfine and A. G. Quarrell, *Journal* of the Iron and Steel Institute, August 1960, Vol. 195, p. 409-414.

Wire Drawing—"Boundary" Lubrication Is Important

The amount of lubricant carried through the die has an important bearing on the amount of reduction possible in drawing.

IN DEEP DRAWING operations such as tube drawing, lubrication plays an important role. The authors have convincingly demonstrated the manner in which boundary lubrication properties of drawing lubricants influence the limits of the severity of reduction in cross section during drawing. For instance, they show that reductions of over 55% can be accomplished in one pass if proper lubricating practices are employed.

In tube drawing, thick-film hydrodynamic lubrication presumably exists under light loads and high drawing speeds in low-angle dies. Under these conditions, the coefficient of friction is low (0.01 to 0.05) and the viscosity of the oil influences friction and consequent drawing stresses. As the die load and the severity of reduction are increased, the lubricant film between the die and the workpiece becomes thinner, and the so-called "boundary lubrication" properties of the oil become more important. This becomes evident when the thickness of the lubricating film approaches the range of the surface roughness. Under conditions of very severe deformation where galling may take place, compatibility between die material and workpiece becomes important. For instance, mild steel can be drawn to

Wire Drawing . . .

much more severe reductions if tungsten carbide dies are used instead of steel dies. Stainless steel, however, cannot be drawn severely with either steel or tungsten carbide dies.

The authors carried out deep drawing experiments with an apparatus designed to exclude thick-film hydrodynamic conditions. By measuring lubricant film thicknesses through the use of radioactive tracer techniques, they were able to determine the amount of lubricant carried through the die on the surface of the workpiece. Finding that the greater the lubricant throughput, the greater the possible reduction in one pass, they increased lubricant trapping on the workpiece surface by grit blasting. Through this technique, reductions in cross-sectional area up to the limit of the tensile strength of the drawn bar were achieved.

Boundary lubrication properties of the lubricant were found to be important even when grit-blasted surfaces were used. For example, although the addition of oleic acid to heptane changed the viscosity only slightly, it improved drawing capacity considerably. Other effective boundary lubricants include soaps, such as stearic acid, lauric acid and lanoline; these soaps are recommended as having better lubricating potential than oleic acid. Coefficient of friction values appeared to increase somewhat with increasing severity of drawing reduction.

When the researchers investigated the drawing of other materials, they found that copper deforms more readily than steel, and that throughput of lubricant on copper is greater. Titanium is very difficult to draw under any conditions unless a barrier layer such as an oxide or phosphate coating is provided. This layer must be produced by a special treatment which is a supplement to conventional deep drawing lubrication.

W. A. GLAESER

Digest of "Mechanisms of Boundary Lubrication — Boundary Lubrication of Copper, Mild Steel and Stainless Steel During Severe Cold Deformation", by P. R. Lancaster and G. W. Rowe. Paper (61-LUBS-5) presented at the Lubrication Symposium, A.S.M.E., Miami, Fla., May 1961.

Large Grains in Austenitic Stainless Steels

Some austenitic stainless steels develop large grains during heat treatment. Slight deformations (before final heating) can lessen this effect.

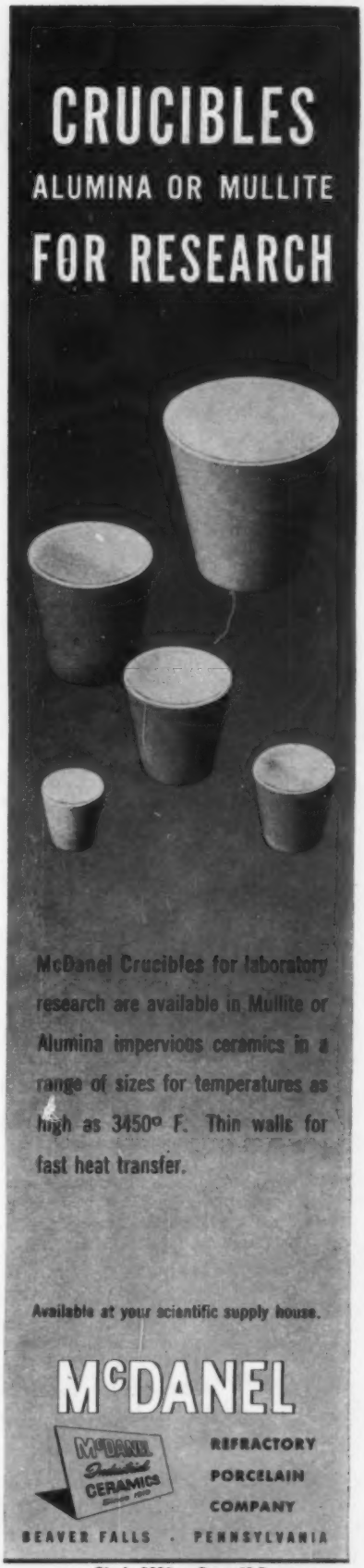
EXPERIENCE WITH CERTAIN heat-resistant austenitic alloys has shown that abnormally large grains are sometimes developed in hot worked materials after final solution or softening treatments at elevated temperatures. Since such grains adversely affect mechanical properties, the present investigation was undertaken to determine the conditions and mechanisms governing their formation, and to develop methods of avoiding abnormal grain growth.

Compositions of the three austenitic alloys employed in this investigation are given in the table below:

	1	2	3
C	0.63%	0.20%	0.22%
Si	0.41	0.74	0.62
Mn	7.45	0.69	1.11
S	0.008	0.012	0.003
P	0.034	0.025	0.015
Cr	4.00	17.52	13.8
Ni	8.35	17.68	9.55
Co	—	6.83	—
Mo	—	2.66	2.18
Cu	—	2.73	2.5
To	—	0.74	0.78

In each alloy, the initial material selected for study was hot-rolled bar of uniformly fine grain size. To simulate commercial fabrication conditions, all samples were deformed by compression in a laboratory test, the extent of deformation being expressed as percent of reduction in thickness. For each alloy, separate samples were deformed by amounts ranging from 0 to 128% at temperatures ranging from 800 to 1150° C. (1470 to 2100° F.). Since the range of grain size encountered in a single sample was often quite wide, the proportion of the several grain sizes in each sample was estimated in terms of the following three categories: (*a*) the preponderant range of grain size; (*b*) a range in which many grains were found but to an extent less than in (*a*); and (*c*) a range in which only relatively few grains were to be found.

Curves included in the original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*Pyro-Eye measuring temperature in a vacuum furnace. Photo courtesy of Richard D. Brew and Company, Inc., Concord, N. H.

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Circle 1921 on Page 48-S

Austenitic Stainless . . .

paper reveal the following features which were confirmed by commercial rolling tests on one of the alloys, No. 3:

- Nondeformed samples of the alloy No. 1 showed only a slight tendency to develop abnormally large grains, while nondeformed samples of alloy No. 3 show a marked tendency toward grain growth.
- Small amounts of deformation applied to both alloys resulted in a progressively finer grain size except at the highest working temperature (1100° C. or 2000 °F.) in Alloy No. 1.
- With further deformation beyond the grain refining range, a second amount of critical deformation is reached which in No. 1 causes, and in No. 3 restores, the tendency to develop abnormally large grains.
- As the deformation temperature increases, the critical deformation for grain refinement or abnormal grain growth decreases for No. 1, but increases for No. 3.

Grain Growth Inhibition

It is well known that the presence of many fine undissolved particles of a second phase can have a marked inhibiting effect on grain growth. In the present investigation, the workers found that there was a relatively small range of temperature below which abnormally large grains could not form in a fixed period of time. This inhibition of grain coarsening was correlated with the occurrence of fine undissolved particles of such phases as TiC.

It is generally conceded that a material must be plastically deformed and contain resultant microstresses before it can be induced to recrystallize. To determine whether hot working of the present alloys produced a stressed condition, recrystallized samples of Alloys 1 and 2 were compressed about 6 to 8% at 800 to 1100° C. (1470° to 2000° F.) and immediately air cooled. Transverse sections were examined by x-ray diffraction for line broadening. From this study, the scientists concluded that such deformations would leave each of the alloys in a state of stress, or incompletely recrystallized. It thus becomes under-

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Nickel alloy carburizing steels sustain powerful punch of heavy-duty drill.

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AISI 3312 and 4620 are just two of many nickel alloy steels that handle rugged jobs in all sorts of heavy-duty equipment. They last longer, perform better, and can be fabricated at practical cost. If you'd like help with your problems in the selection of alloys, simply write to Inco describing them.

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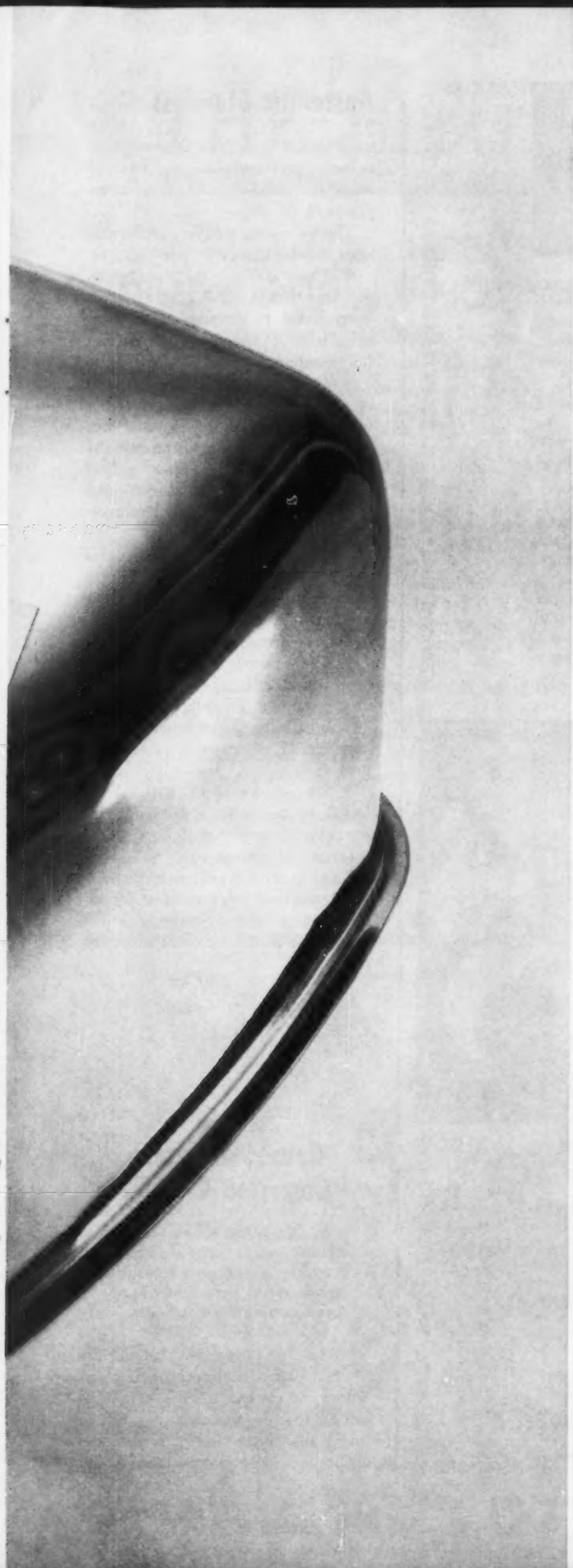

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How a "specially tailored" strip reduces production rejects almost 25% for Kromex

Kromex, Inc., Cleveland, Ohio, turns out a complete line of pantry ware, but they were having trouble with a square, mirror-finish chromium-plated cake cover that was made with a single deep draw. Rejection rate was a stunning 25%. They first tried a No. 3 finish for this application, but because of the very deep draw and the dense and smooth surface, satisfactory lubrication was near impossible. The result: Excessive draw marks and breakage. A regular No. 2 finish was then tried. The draw was successful. But buffing and finishing costs were prohibitive for this application.

American Steel and Wire salesmen conferred with our Metallurgical Department and suggested a specially tailored No. 3 finish. Reject rate dropped to less than 1% because the special surface was able to hold lubricant evenly, but smooth enough to draw and plate flawlessly.

Kromex is one more example of how strip, *tailored to end use,* works to produce a better product at lower cost. When you buy strip, you're buying a specific chemistry, temper, dimension, edge and finish that is consistently uniform within the coil or from coil to coil. Certain of your processing steps may actually be eliminated by using cold rolled strip, produced in our mills, and tailor-made for your specific end use.

Take a hard look at your production line and let our salesmen and metallurgical people look too. There's a good chance you can improve quality and cut production costs at the same time with *tailored-to-the-job* cold rolled strip from American Steel and Wire. American Steel and Wire Division, Rockefeller Bldg., Cleveland 13, Ohio. *USS and American are registered trademarks.*

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LCA-Developed Lithium Vapor Generator Eliminates Scale Formation

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The Lithium Vapor Generator is essentially a compact combustion chamber that can be attached to the wall of the hot mill or furnace. It is fitted with a standard gas burner that utilizes plant fuel gas. Electrical controls are contained in a separate panel box that can be mounted nearby or at a remote point.

The source of lithium vapors is a cylindrical cake consisting of a mixture of lithium chloride and lithium carbonate. Each unit charge contains 7⅛ ounces of the salt, an amount ordinarily sufficient for an eight-hour run.

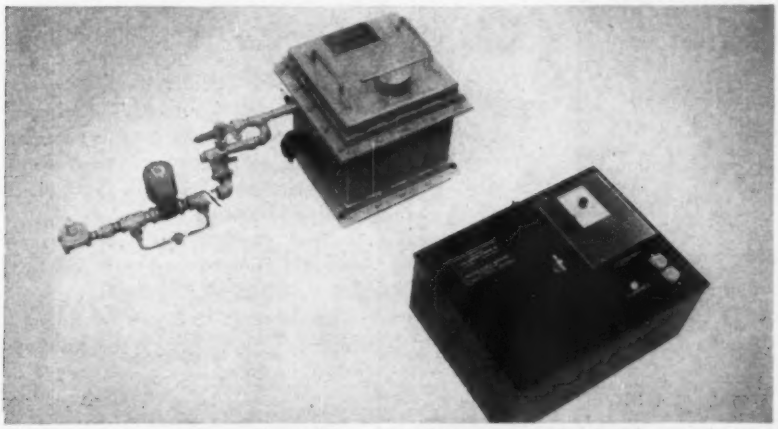
Introduction of the lithium-compound vapor into the working atmosphere produces a three-fold action:

1. It controls the oxide-forming gases to provide a protective atmosphere.
2. The vapors are adsorbed on the surface of the metal, forming a protective coating that also acts as a die lubricant in rolling and drawing.
3. The vapor diffuses into the refractory lining of the generator and mill, and feeds back into the working atmosphere to maintain equilibrium during the operating cycle.

The new method not only solves the problem of scaling as such, but can also eliminate pickling...produce raw materials savings...economize on labor...reduce the housekeeping problems associated with abundant scaling...prolong roll life in rod mills.

The Lithium Vapor Generator requires a minimum of operator attention and maintenance. It is constructed for easy dismantling and inspection. Use of standard components insures immediate replacements if accidental damage occurs.

The lithium compounds used are nontoxic under recommended conditions of use and present no hazard either to men or machines.



Generator consists of a small metal box, 15 inches on a side, fitted with a gas burner. Separate panel box contains electrical controls.

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A valuable complement to the Lithium Vapor Generator is the LCA Lithium Copper Cartridge for inoculating copper melts. The cartridges provide a means for injecting lithium directly into molten metal. Thus applied, the lithium scavenges out oxygen and other occluded gases, increases fluidity, lowers pouring temperature and refines the grain.

The cartridges are conveniently sized to contain .005, .01, .02 and .24 pounds of lithium metal. Though requirements for lithium vary with condition of melt, a basic charge of one part lithium to ten thousand parts copper is indicated. Thus, melts from fifty pounds to twenty-four hundred pounds of copper can be treated with a single appropriately sized cartridge.

The thin-walled cartridges give fast reaction in the ladle. Their thin design provides ease of handling and storage. The special hermetic seal insures permanent shelf life of the contained lithium.

LITHIUM IN BRIEF

New developments involving lithium are constantly appearing in the literature. Each month some will be mentioned here briefly.

Silver-copper alloys with minor additions of Li, indium and palladium are used in bonding stainless steel honeycomb. As little as 0.2% Li in the ternary alloy makes it suitable for this purpose. Use in the B-58 and B-70 structures is described. (6770)

Ag-Cu-Li brazing compositions are commercially available for joining noble metals. The addition of 1% lithium confers self-fluxing properties as well as improved wetting and spreading. Ag-Li filler has been used to braze beryllium sandwiches. (4973)

Analytical data were plotted and discussed for Li-Mg alloys. (4817)

Aluminum alloys containing 0.5-2.0% Li and small percentages of Cu alone or with Mn and (in some cases) Cd were studied. Li additions increase strength in the aged alloys. (4864)

For further information, write our Technical Service Dept., Bessemer City, N.C.

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Circle 1928 on Page 48-8

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Circle 1929 on Page 48-B

be expected from the sum of the individual effects of stress and corrosion.

In fact, the extent of stress corrosion seems to be controlled by five principal variables: alloy composition, tensile stress, corrosion environment, temperature and time. As far as is known, pure metals are not susceptible to stress-corrosion cracking. Thus alloys which have been made from pure metals have shown marked improvement in resistance to the phenomenon. Susceptibility to this type of cracking also decreases as alloying constituents decrease.

Only tensile stress at the surface of a metal causes stress-corrosion cracking. Furthermore, the tendency to crack increases disproportionately with stress, particularly at loads approaching the yield point. Residual and applied stresses are additive.

In general, cracking susceptibility also increases with increasing temperature, exposure time and concentration of corrosive ingredients in the surrounding environment. Too, it should be noted that stress-corrosion cracking is not limited to an aqueous system, but has been observed in liquid metals, molten salts and in organic solutions.

Stress-corrosion cracking may be minimized or avoided through adjustment of as many controlling variables as possible. As examples, stresses can be reduced through the use of lower pressures, improved parts alignment, stress relief of weldments and increased section thickness. Swaging, shot-peening and other treatments by which the surface can be placed in compression also may be effective. Cathodic protection to decrease corrosion, and removal of corrosive ions from aqueous solutions, also have had beneficial results.

The paper illustrates recommended equipment design concepts for minimizing stress-corrosion cracking, and includes a bibliography of more than 100 references on the subject.

J. L. Wyatt

Digest of "Stress-Corrosion Cracking — a Nontechnical Introduction to the Problem", by Warren E. Berry, Defense Metals Information Center Report 144, Jan. 6, 1961, Battelle Memorial Institute, Columbus, Ohio.

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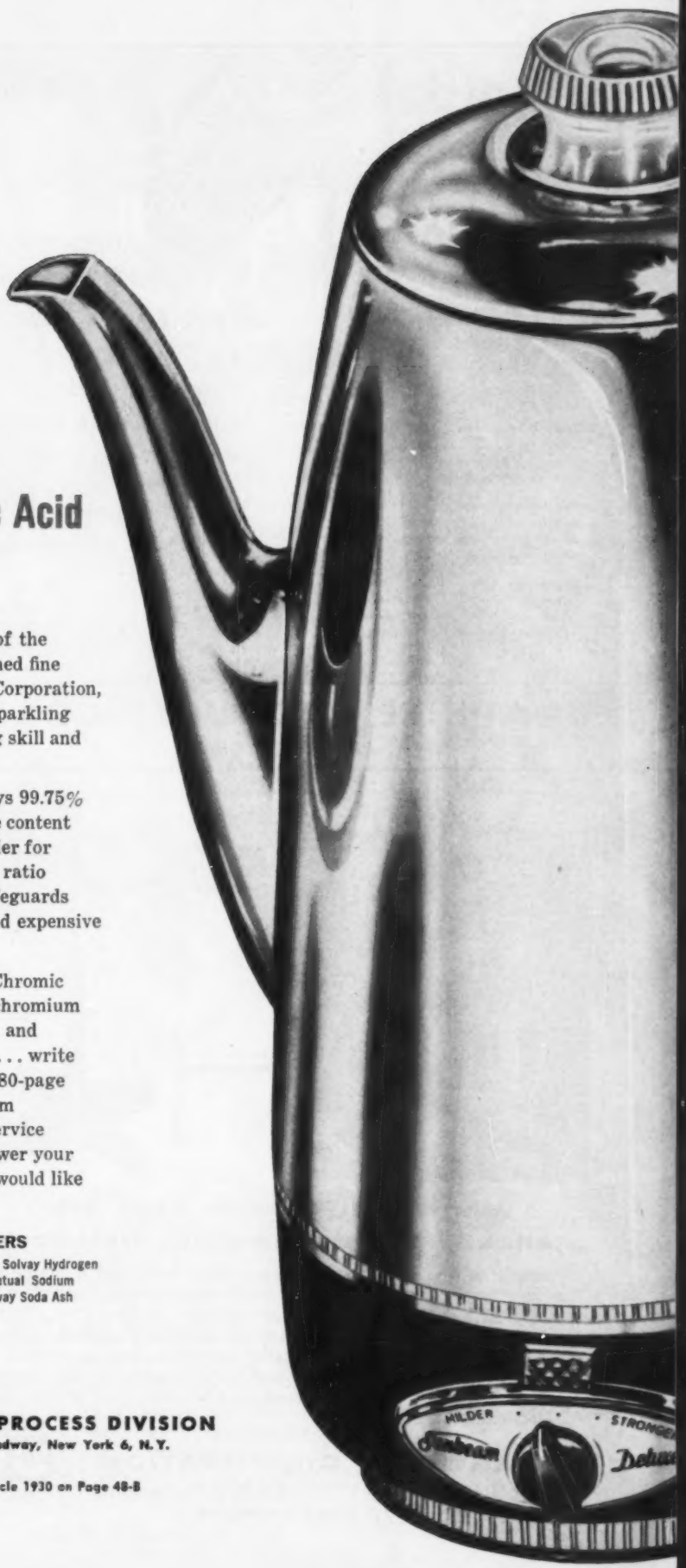

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Circle 1930 on Page 48-B

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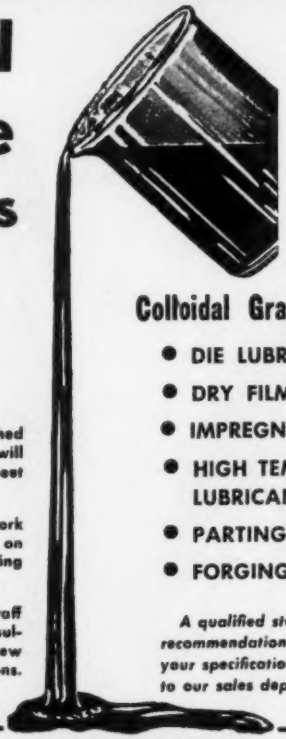

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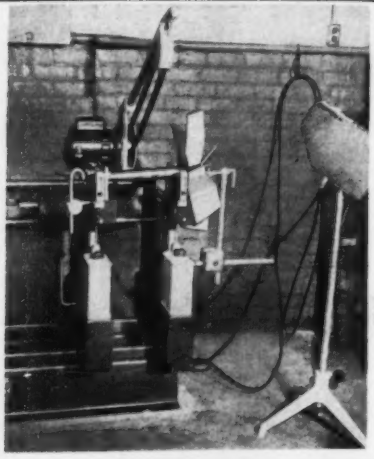
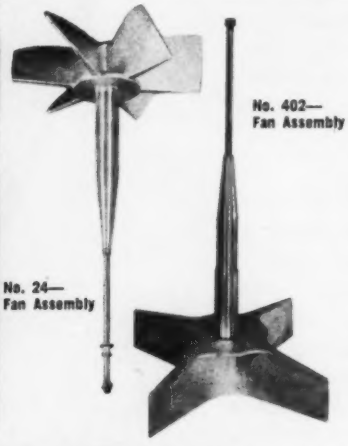
Circle 1931 on Page 48-B





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HEAT TREATING EQUIPMENT

Circle 1932 on Page 48-B

Testing Steels for Low-Temperature Use

For rating steel to be used in low-temperature applications, the notched and welded wide plate tension test gives the most comprehensive results. Minimum values of 35 ft-lb. and 30% fibrous fracture are suggested as specifications for steels in as-welded structures.

THOUGH THE CHARPY TEST has proved useful for quality control, and has achieved a degree of success in correlations with brittle fracture casualties, engineers would prefer a test that simulates actual structural behavior more closely. To answer this need, tests have been developed for welded structures — the Pellini drop-weight test, and the notched and welded wide plate tension test. The former, however, has the disadvantage of small size, and more comprehensive results are obtained from the latter.

In the wide plate test, which is essentially a static tension test on a centrally notched and welded plate, three types of fracture may be obtained — a full width fracture, with or without yielding, and a low-stress short fracture. Experimenters have shown that the Robertson crack-arrest test separates the arrested from the through-fractures, and Pellini's "nil ductility" temperature correlates with the transition from low-stress to high-stress fractures. Agreement has also been found between low-stress fracture probability and Charpy V energy absorption of material in the strained and aged condition.

There are three important variables in the wide plate test: the notch length normal to the applied tension, the prior plastic strain (and aging) at the notch root due to welding, and the residual tensile stress around the notch. Notches cut after welding are less severe than those cut before welding, and mechanical or thermal stress relief produces a significant improvement in strength.

For structures operating at low temperatures, impact testing alone does not always tell the full story. As an example, one steel was capable of giving low-stress short fractures at a temperature corresponding to 40 ft-lb. energy absorp-

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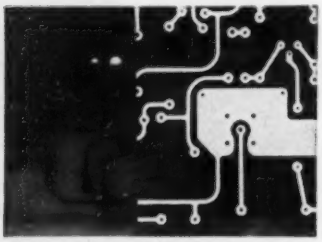
Circle 1933 on Page 48-S

Straits Tin Report

Chemical tinning enhances the solderability of the conductive paths of printed circuits. Pure tin is deposited only on metal surfaces, including exposed edges; dielectric properties are unchanged.

The new process, using "CUPOSIT LT-26," made by Shipley Co., Inc., Wellesley, Mass., is not a substitute for electrodeposited tin, but it affords protection to the printed circuit board, thereby increasing storage life. "CUPOSIT LT-26" operates at temperatures lower than hot tin dipping, requires no electricity, contains no cyanide.



Bright side of printed circuit shows results of immersion in new chemical tinning process.

Tin Developments

• *Stronger titanium* results from addition of 15% tin. Ultimate tensile strength increases 90% at room temperature.

• *High-temperature brazing filler* metal alloys of tin, nickel, chromium, silicon keep joints strong after long exposure at high temperatures.

• *Low-melting quaternary* alloys of tin, indium, lead, silver are used for cryogenic circuits.

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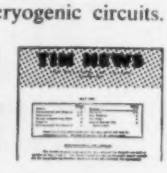

The Malayan Tin Bureau
Dept. T-25L, 2000 K Street, N.W., Washington 6, D.C.

Circle 1934 on Page 48-B

Low-Temperature . . .

tion and 20% crystallinity. If leakage were a hazard, as in certain pressure vessels, the use of this steel would be unwise.

In the wide plate test, thermally stress-relieved samples have been considerably superior to as-welded samples. Results indicate that stress-relieved, fully killed, mild steels should be satisfactory down to −120° F. at least. For large structures, such as storage vessels and pipelines, local treatments are probably essential, and mathematicians have calculated acceptable band widths of temperatures needed for local stress relief of butt welds in cylinders and between pairs of plates. Wide plate tests will be made to check the influence of the level of reduction of residual stress on the measured extension to brittle fracture.

Design Code Requirements

A general pattern covering non stress-relieved construction can be seen. It is apparent that many applications for common mild steels exist, even when service temperatures may fall below the transition values. Of course, extra conservatism is necessary where application of a substantial pre-service overload is impracticable, where failure on the first load application would have catastrophic consequences, or where partial failures are a normal and acceptable operational hazard. If the structure has been subjected to a pre-service overload, operation at temperatures below the transition value is acceptable. And finally, when service loads at low temperatures are a small fraction of normally acceptable values and much below a previously applied load, no special precautions are required.

On the basis of wide plate test data, it can be concluded that the brittle strength of a structure will not be less than any previously applied load of the same general pattern. Hence, the minimum factor of safety may be assumed to be the ratio of the maximum applied load (the test pressure load, for

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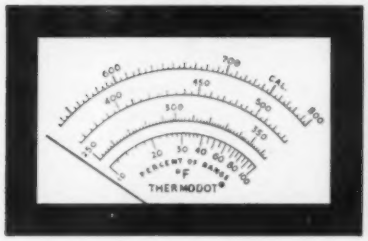
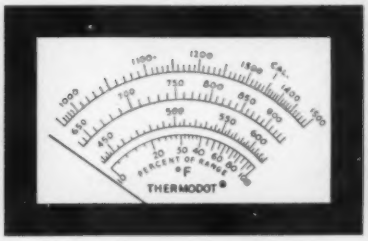


430-1500°F



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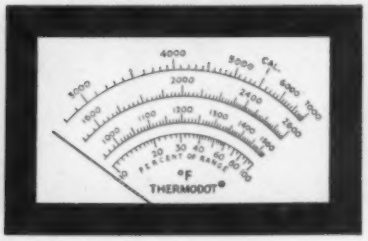

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Circle 1958 on Page 48-8

Low-Temperature

instance) to the operating load.

This conclusion only applies to service loads of the same pattern. For example, brittle fracture could be initiated, if the service conditions at some time resulted in tensile stresses in regions which had been stressed in compression by the preload. Furthermore, initiation of brittle fracture may be predicted if additional loads or thermal stresses occur under operating conditions.

For nonstress-relieved vessels at temperatures down to about −20° F., both British and American codes permit the use of common mild steel, although much of the steel will probably have transition temperatures above this level. This policy may be satisfactory for the thinner plate (although it appears to be less conservative than for refrigeration practice), but it is noteworthy that the British code is more conservative than the American for thicker plate.

The specification of a minimum Charpy impact strength of 15 ft-lb. has found ready acceptance for ferritic steels, but the satisfactory record of welded vessels operating below −20° F. is largely confined to equipment which has also been thermally stress relieved after fabrication. Wide plate data suggest that notched welded specimens tested in the stress-relieved condition are generally superior to similar specimens tested in the as-welded condition at much higher temperatures. It would appear, therefore, that steels similar to A.S.T.M. A285 could safely be used in stress-relieved structures down to at least 180° F. below a conservatively estimated 15 ft-lb. transition temperature.

Though stress relieving small vessels generally presents no problems, it is less simple for vessels used in the large-scale storage of refrigerated liquid. Actually, the designer has three alternatives: He can use (*a*) a steel which will be completely resistant to brittle fracture initiation in the as-welded condition, even if subjected to appreciable plastic deformation in service; (*b*) a steel of moderate notch ductility at service temperatures, with thermal stress relief after fabrication; or (*c*) a common mild steel, coupled with design refinement to minimize stress raisers, and a thorough inspection procedure.

For the first procedure, engineers must still rely upon Charpy tests, since the more sophisticated tests are not yet acceptable to steelmakers in general. While the requirement of 15 ft-lb. impact energy may be adequate for stress-relieved equipment, it is evidently unsatisfactory for all classes of ferritic steel in as-welded construction. Data from the wide plate test, however, suggest that the dual criterion of Hodgson and Boyd, 35 ft-lb. and 30% fibrous fracture, would exclude nil ductility features in most instances. Application of this criterion would appear to provide a high, but undiscriminating, degree of assurance of satisfactory performance for steels of the types examined in as-welded structures.

R. C. A. THURSTON

Digest of "Welded Ferritic Steel Construction for Intermediate Low-Temperature Service", by A. A. Wells, A.S.T.M. Preprint 80C.

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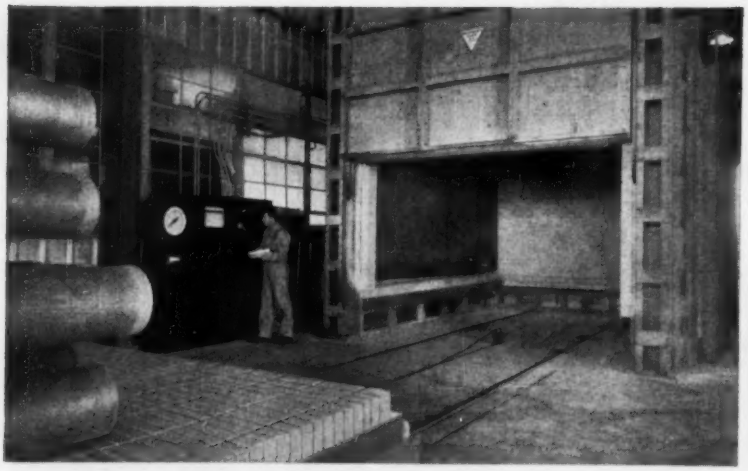

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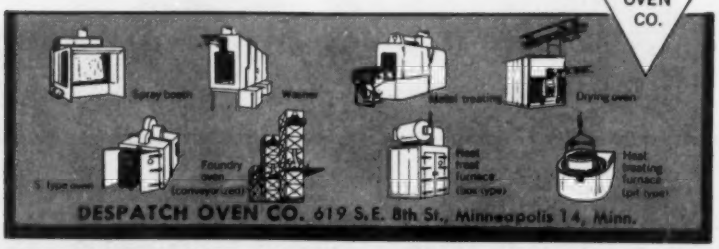


DESPATCH—INDUSTRY LEADERS FOR 58 YEARS

Circle 1936 on Page 48-B

Treating Semikilled Steels With Columbium

Columbium, in amounts up to 0.03%, increases the yield and tensile strengths of plate made of low-carbon semikilled steels. Formability and weldability of the steel are adequate for fabrication.

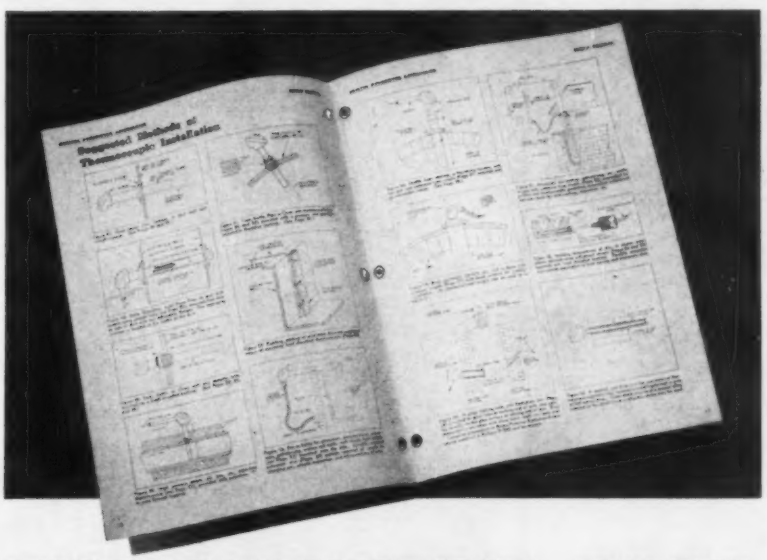
SEMIKILLED STEELS containing 0.16 to 0.24% C and 0.65 to 1.10% Mn are widely used for structural purposes. The suitability of a steel for such applications depends on its strength, toughness, weldability, and forming characteristics. This article describes the effects of small columbium additions on these properties.

The yield and ultimate strengths of hot rolled plates, in thicknesses up to 1½ in., increase regularly with columbium contents ranging up to 0.03%. For example, samples from the inside of a coil of 5/16-in. plate containing 0.03% Cb had yield and tensile strengths of 56,000 and 81,200 psi., respectively. These values are considerably higher than those of 45,000 and 76,000 psi. reported for columbium-free specimens from the same heat and coil location. The fact that columbium raises the yield strength more than the ultimate strength is advantageous for many applications. In the hot-rolled condition, the properties of a columbium-treated steel are significantly affected by the rate at which it cools from the finishing pass. For example, the yield and ultimate strengths of specimens from the outside of the coil of 5/16-in. plate of columbium steel were 6500 psi. higher than those quoted for the inside location. The yield and ultimate strengths of the columbium-free samples representing the two coil locations agreed within 1100 and 2700 psi., respectively. Despite the influence of cooling rate, columbium produced substantial increases in strengths in plate thicknesses up to 1½ in.

However, the increases in yield and tensile strengths were accompanied by a loss in ductility as measured by tensile elongation values. The author reports that the columbium-treated steels exhibit good forming properties. Steels with yield strengths around 60,000 psi. have been used commercially for wheels and stampings. Laboratory tests indicate that the columbium-treated steels can be welded by normal practice. The presence of columbium did not affect the tendency for underbead cracking. Meager Charpy data indicate that columbium improves the toughness of semikilled steel. This attribute is important especially for structural components with heavy sections. For the hot-rolled condition, best results are obtained when the A.S.T.M. grain size is No. 6 or finer. Normalizing will refine the coarser sizes associated with higher finishing temperatures and heavier gages.

In amounts up to 0.07%, columbium substantially lowers the hardenability of these semikilled steels. Increasing the columbium content above 0.07% then gradually raises the hardenability. Tempering oil-quenched samples of columbium-treated steels for 5 hr. up to 1200° F. did not affect low-temperature Charpy properties adversely.

The higher strengths of the



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Circle 1937 on Page 48-B

Semikilled Steels . . .

columbium-treated, hot-rolled steels permit weight savings of 20 to 40% in applications such as beams and pressure vessels. For equal design strengths, cost savings range from 10 to 35%, depending on the application and grade of steel used.

F. W. BOULGER

Digest of "Columbium-Treated Mild Carbon, Semikilled Steels", by C. L. Altenburger. Paper presented at the A.I.S.I. Regional Technical Meeting, Buffalo, N.Y., 1960.

Welding Molybdenum Tubes

Techniques for welding tubes from thin-walled molybdenum sheet are described.

THIS WELL-WRITTEN article presents useful information for one who plans to weld tubing of thin molybdenum sheet (here, 0.015 in.). A schedule of operations arranged as a flow chart is given, individual operational procedures being thoroughly detailed. Procedures for removing oxide scale from the sheet before welding are somewhat extensive but are effective.

Nothing new or unorthodox is described although ingenuity is exercised in applying the automatic inert-gas-shielded arc, helium being used as the shielding gas for both face and root sides of the weld joint. Data describing the results are limited to tests of a fabricated unit, and no figures are given for resultant mechanical or metallurgical properties. Such information, however, is available in the references and is extensive and complete in details. To these references should be added the DMIC Report 108, "Welding and Brazing of Molybdenum", by N. E. Weare and R. E. Monroe.

W. T. TIFFIN

Digest of "The Fabrication of Thin-Wall Molybdenum Shapes by Welding", by W. F. Brown and M. A. Pugacz. Paper (60-WA-53) presented at the Winter Annual Meeting of the A.S.M.E., New York, November 1960.

Strengthening Stainless Steel by Cold Working

Bars of Type 304 can be strengthened to a minimum yield strength of 100,000 psi. by cold straining. After straining, the bars must be aged to prevent dimensional instability.

THE COMPONENTS of many nuclear, rocket and aerospace devices make wide use of sandwich structures because they have a high strength-to-weight ratio. These assemblies use half-hard Type 301 stainless steel for the skins because it has a minimum yield strength of 110,000 psi. However, the size of the units is limited by the size of the available sheets. Therefore, when panel sections must be joined, they are welded to annealed and machined joining bars of stainless steel. Originally, these bars were lightly loaded so the low strength of the material was satisfactory. However, as conditions changed and

(Right) Model RDB-47 Box Furnace. This is an extremely versatile unit capable of a variety of non-atmosphere applications where a continuous operating temperature up to 2250°F. is required. Heating chamber is 14¼" deep, 8½" wide, 5½" high. Atmosphere requirements for temperatures up to 2050°F. can be handled in a gas tight retort with working dimensions of 3½" high, 13" deep, 7½" wide. *Write for Bulletin No. 1086.*

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(Left) Model RB-45 Atmosphere Box Furnace. This unit is suitable for a wide range of heat treating applications at all heat levels up to 2000°F. where atmosphere is required. Clear working area is 9" wide by 13" deep by 5" high. Complete with automatic flame curtain, flowmeter, atmosphere burn-off and all necessary electrical components. *Write for Bulletin No. 1096.*

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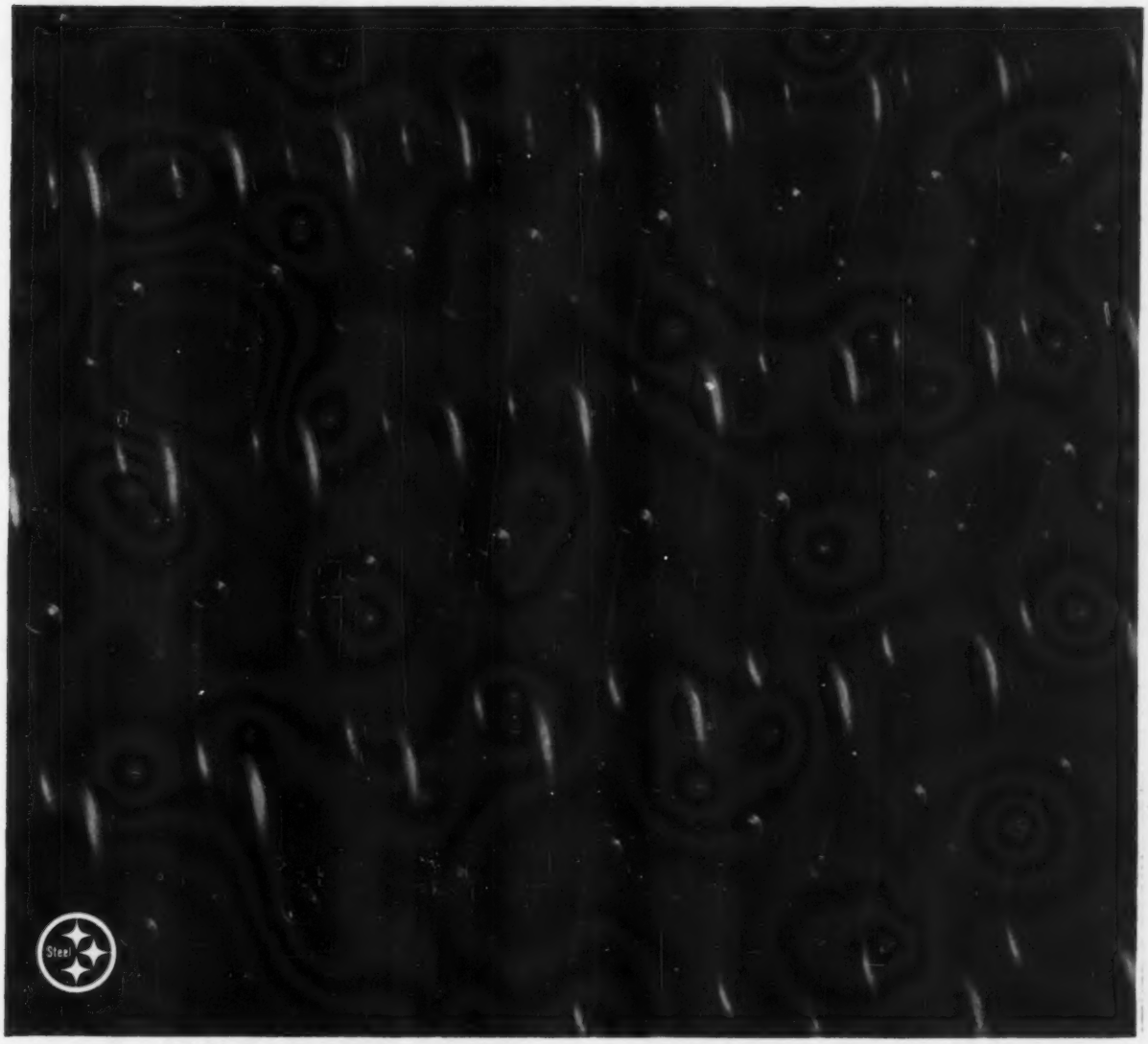

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Circle 1939 on Page 48-B

Stainless Steel . . .

the operating temperatures rose, designers needed stronger materials with yield strengths of about 100,000 psi. Since these were not available commercially in sizes over ¾ in. in diameter, alternatives were needed.

The first substitutes considered were the precipitation-hardening and the heat treatable stainless steels. These were rejected for two reasons: Their coefficients of expansion were not compatible with that of the skins, and they would require postfabrication heat treatments that were not practical. As a result, a developmental program was conducted to determine whether high-strength bars of austenitic stainless steel could be produced by cold straining in tension.

Standard tensile specimens of Type 304 stainless steel, used in rating the uniformity of straining, showed that both the necked and unnecked portions of the bars were hardened and strengthened by the tensile straining. As would be expected, the strength of the necked portions of the bars was much higher than that of the unnecked portions, but the strength of the unnecked portion was more uniform. When the effects of chemical composition and previous rolling history were also studied, the researchers found that both factors had a considerable effect on the work-hardening rates.

Square bars ranging from 34 to 168 in. in length were strained with and without reduced cross sections to determine the optimum configuration for uniform strain. After each bar was strained, its properties were rated by testing a standard tensile bar sectioned from it. True stress-strain curves, used to evaluate the results, revealed that the amount of strain needed to obtain 100,000-psi. minimum yield strength varied from 18 to 40%.

Tests were also conducted to determine the effect of stabilizing at 800° F. for 2 hr., since the operating temperature of the bars would be 700° F. Though the treatment had little effect on the tensile and yield strengths of the strained bars, the lengths changed by an amount sufficient to indicate that a stabilizing treatment was necessary.

The following conclusions were based upon the test results obtained:

- Type 304 stainless steel can be strained to a minimum yield strength of 100,000 psi., and higher values seem to be readily obtainable.
- The use of "true stress versus strain" plots will help minimize variations in straining characteristics.
- If necking does not occur, neither bar lengths nor geometry will affect the uniformity of the properties obtained, regardless of percentage of strain.
- To avoid dimensional instability (with its possible resultant build-up of residual stresses), the bars must be aged after straining.

BERNARD TROCK

Digest of "Strain Strengthening of Type 304 Stainless Steel," by Walter Hammer, Jr., Leonard Stemann and E. E. Weismantel. Paper (Preprint 83) presented at 64th Annual Meeting, A.S.T.M., Atlantic City, N.J., June 1961.

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INCONEL* alloy 718 is the strongest wrought alloy available for use in the temperature range 800°—1300°F, filling a gap between the martensitic stainless steels and the high temperature "super" alloys.

INCONEL alloy 718 is hardened and strengthened by a coherent face centered cubic precipitate of nickel, columbium and molybdenum. The precipitate has a lattice parameter of 3.631 as compared with a value of 3.601 for the matrix—a misfit of 0.8%. This is substantially higher than the misfit obtained with the usual Ni_3 (Al, Ti) type of gamma prime precipitate, accounting for the higher strength of the alloy.

Figure 1 illustrates the tensile properties of the alloy from room temperature to 2000°F. Like all other nickel-base alloys, the strength increases at subzero temperature with little loss of ductility. Tests at minus 320°F showed an increase of about 20% in tensile strength over room temperature results. Figure 2 shows stress-rupture properties, illustrating the good notch ductility of alloy 718.

Another notable feature of INCONEL alloy 718 is its high fatigue strength, especially in corrosive environments. Recent room temperature tests on hot rolled, annealed aged bars showed a fatigue limit of 89,000 psi (unbroken at 10^8 cycles) in air, and 60,000 psi in sea water.

INCONEL alloy 718 can be welded in the age-hardened condition. This is important because it permits repairs or final closures on age-hardened components. Good ductility of the age-hardened alloy enables it to withstand residual welding stresses. Pre- and post-welding stress-relief heat treatments, required by other alloys, are seldom necessary.

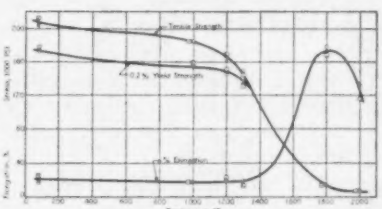

FIGURE 1

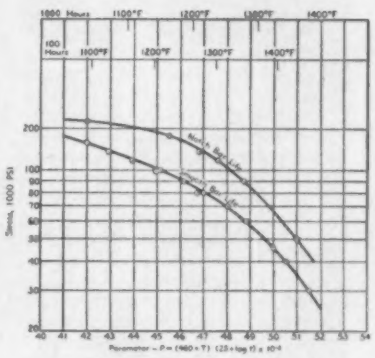

FIGURE 2

Slow aging response aids forming. Alloys hardened with aluminum and titanium must contain relatively large amounts of these elements in order to obtain useful property levels. This has the unfortunate result of greatly increasing the speed of age-hardening. Therefore, when a part is annealed to relieve the cold work of forming, it must be cooled rapidly or quenched to prevent hardening while cooling through the 1500°—1200° F temperature range. INCONEL alloy 718, hardened by columbium, can be heated and cooled through the aging temperature range at *normal speeds* while maintaining softness and ductility. Figure 3 shows the aging response of mill annealed sheet for various temperatures and times. As can be seen, *virtually no hardening* occurs in the first two or three minutes of exposure in the age-hardening temperature range. (In contrast, aluminum-titanium hardened alloys containing sufficient hardener content to approach the strength level of INCONEL alloy 718 would develop high hardness in the same period of time).

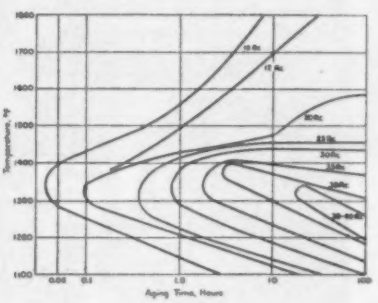

FIGURE 3

What are your alloy requirements? If you have need of an alloy with high strength at temperatures up to 1300°F, unusual corrosion-fatigue resistance, and simplified fabrication methods, investigate INCONEL alloy 718. Write for our Current Data Report—INCONEL alloy 718.

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Circle 1941 on Page 48-B

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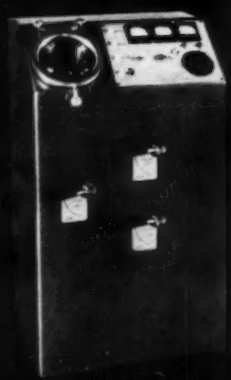

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Circle 1961 on Page 48-B

Increasing the Corrosion Resistance of Plated Parts

A more rapid test for determining corrosion on plated automobile parts has helped to improve corrosion resistance.

THE AUTHORS describe work for improving the reliability and reproducibility of the CASS test (copper chloride, modified acetic acid, salt spray), used to predict the outdoor corrosion resistance of electroplated automobile parts. They indicate, in fact, that corrosion resistance of plated parts has improved significantly since the beginning of the 1959 model year, when the CASS test came into fairly general use.

The authors report progress in the area of improving CASS test controls and operations. Important variables that require control are:

1. Volume of corroding solution contacting the tested surface. The volume is controlled by proper atomization of the solution to provide a fog-settling rate within specified limits. This requires that the nozzles be controlled; a length of 0.5 mm. glass capillary is suggested as a restrictor to prevent flooding in the nozzle throat.

2. Relative humidity of the atomizing air. The air should be as nearly saturated as possible (incomplete saturation results in evaporation of water from fog, and oversaturation results in dilution of fog).

3. Water height in bubble tower. Incomplete humidification of air will result if the water is shallow. Therefore, automatic water level controllers are recommended.

4. Uniformity of specimen preparation. Because CASS test results correlate with those from outdoor performances when specimens are cleaned with magnesium oxide, it is suggested that magnesium oxide cleaning be standardized.

The authors state that, since the corrosion observed in specimens subjected to the 16-hr. CASS test is similar to that noted on specimens subjected to one year of service in the Detroit area, the mechanism of corrosion is the same. To obtain information on the nature of the corrosion process, steel panels plated uniformly with copper and nickel, as well as various chromium plates were exposed to the CASS solution. Then, the solution was collected as it dropped from the specimens, and analyzed. From these analyses, it was determined that the nickel content of the solution was related to the corrosion of the steel. Tests conducted for 96 hr. showed uniform corrosion of nickel in the absence of a chromium plate; the nickel corroded uniformly and no rust was observed. However, many rust spots appeared with a 0.006 mil coating of chromium, but no rust spots appeared with a chromium coat of 0.046 mil.

The rate of corrosion of nickel in chromium-plated nickel is greatly influenced by the ratio of nickel to chromium area, decreasing as the ratio increases. When the chromium thickness is at least 0.03 mil plated on 1.0 mil of nickel, no basis-metal corrosion is observed in four-day CASS tests. It will be interesting to learn if practical control of the nickel-to-chromium area ratio will limit the nickel penetration rate.

F. H. BECK

Digest of "A Progress Report on Experiences in Improving Corrosion Resistance of Automobile Parts", by J. D. Thomas, D. W. Hardesty, and C. F. Nixon. Paper presented at the 47th Annual Convention of the American Electroplaters' Society, Los Angeles, July 1960.

Cladding Steel to Improve Corrosion, Wear and High-Temperature Properties

Through the use of specially designed equipment, welders can make overlays of uniform depths and penetrations up to 3 in. in width.

FOR THIS WORK, special equipment has been developed, built, and successfully tested, to deposit overlay (up to 3 in. wide) of uniform thickness and depth of penetration. The gas-shielded direct-current arc permits wide latitude in the selection of overlay materials. For example, nickel, Monel, and Type 308 ELC and 309 stainless steel have

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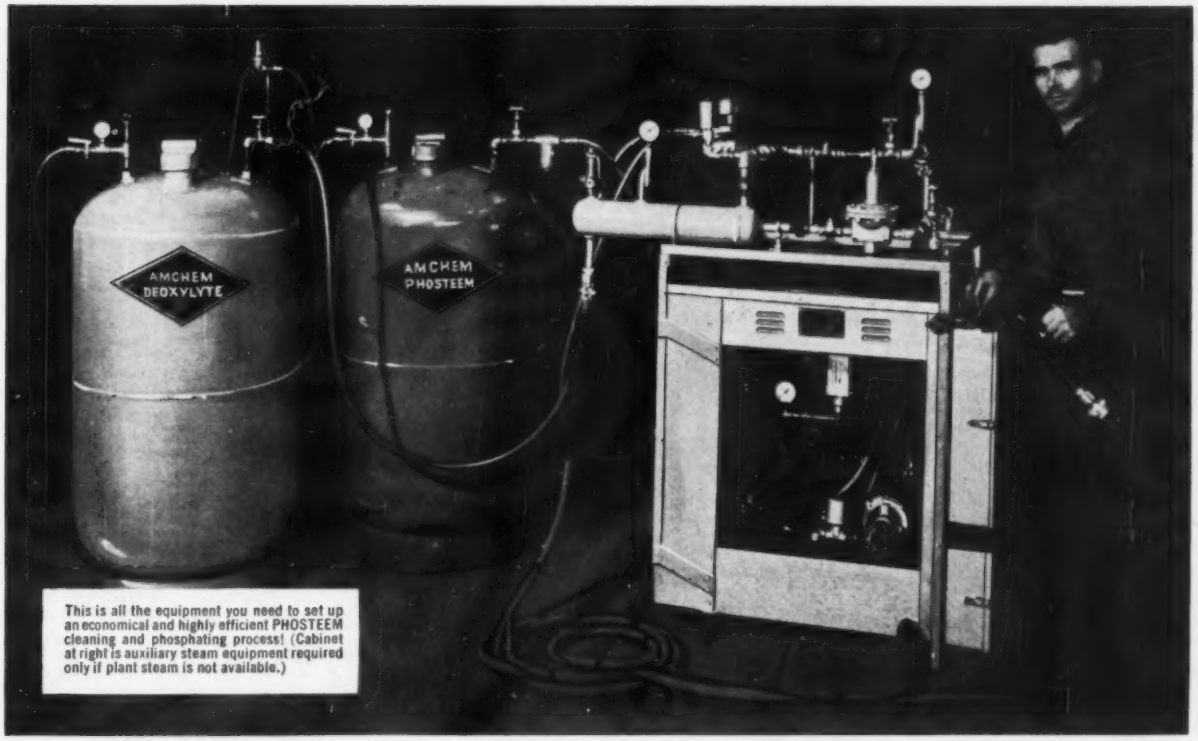

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Photo courtesy of the Electro Steam Generator Co.

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Circle 1942 on Page 48-B

Cladding Steel . . .

been used in these tests, and there is ample reason to assume that any wire presently being employed by the gas-shielded arc process can also be used. The same consideration applies to the base metal.

To explain the value of this technique, readers should know that, in conventional overlay procedures, the weaving motion of the arc produces a short dwell when the electrode direction is reversed. Thus, at the dwell point, there is a somewhat heavier buildup and a deeper penetration into the base metal. Weld metal is also diluted to a greater degree. However, this new technique employs a constant-velocity cam mechanism to oscillate the electrode along a saw-tooth pattern. The result is an overlay bead of uniform thickness, depth of penetration, and with no end dwell.

A most interesting part of the paper is the author's account of the ingenious application of know-how to prevent arcing of the filler wire inside the electrode welding barrel. To attain maximum heating of the electrode wire prior to arcing, the point of current contact with the wire was moved back as much as 3 in. from the point of arcing. This provided for a 3-in. length of wire between the contact point and the work. However, when the arc current was initiated, the wire heated up and exploded. To overcome this, a combination contact-and-guide tube was installed at the exit in the electrode welding barrel. This tube served as a contact for the arc initiating current, and also as a guide for the electrode wire. For starting, the arc current flows through this contact point. As soon as the arc is established, however, the current is automatically shunted through the extension contact which is approximately 3 in. from the arc. This "electrode extension" permits additional heating of the electrode before deposition. The author reports that the technique achieves "a considerable increase in deposition rate accompanied by an appreciable decrease in penetration". Wire speeds of 400 ft. per min. were obtained at an electrode extension of 2⅛ in. while a speed slightly in excess of 250 in. per min. was obtained at an electrode extension of 1 1/16 in. (The electrode used was a 1/16-in. diameter titanium-stabilized nickel-base wire.) In other tests, a 3/32-in. diameter Type 308 ELC wire was deposited at a speed of about 70 in. per min. at an electrode extension of 1 in. and a current of 300 amp. At an electrode extension of 2¾ in. and a current of 400 amp., the wire speed was approximately 180 in. per min.

The paper presents a number of other illustrations of overlays deposited by this technique and data listing current values, deposition rates, electrode speeds, and rate of surface coverage. W. T. TIFFIN

Digest of "New Techniques for Cladding with the Gas-Shielded Process", by Ralph D. Engel. Paper presented at 41st Annual Meeting, A.W.S., Los Angeles, April 1960.

2900° F and 2300° F
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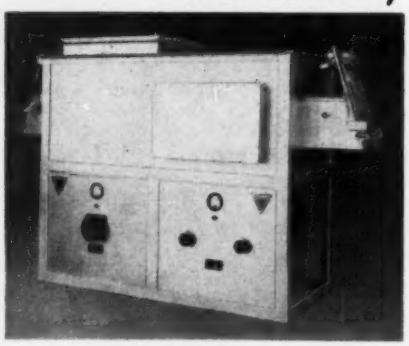

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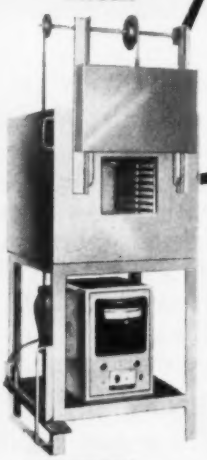

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Circle 1944 on Page 48-B

NUCLEAR GRAPHITE NEWS
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Through its combination of unsurpassed research, engineering, and production facilities for nuclear graphite, NATIONAL CARBON is fully equipped to meet the special needs of the industry. NATIONAL CARBON invites discussion of any potential application of graphite.

Building of Test Reactors Continues Under University Research Programs

This graphite reflector for a test reactor is similar to the type now being constructed for the Georgia Institute of Technology by O. G. Kelley & Company

More and more colleges and universities are expanding their research programs to include nuclear reactors. One of the latest additions at the university level is the nuclear facility now under construction on the grounds of the Georgia Institute of Technology in Atlanta, Georgia.

Nuclear graphite from NATIONAL CARBON is used in the reflector, which is similar to the type shown in the above illustration.

The Georgia Tech Research Reactor was designed to satisfy as many requirements in a broad research program in nuclear science as possible. Its breadth of utility not only embraces classroom practices and material testing, but also serves as a basic research instrument for advanced experimentation, including medical research.

The Georgia Tech reactor is very similar to the CP-5 Argonne Research Reactor and, in some respects, the MIT reactor. It will have an initial power rating of 1000 kw, with an eventual capacity of 5000 kw.

Since its pioneering use in the first reactor at Stagg Field, University of Chicago, "National" nuclear graphite has been increasingly employed in applications such as: moderator, reflector, thermal column, fuel element concepts, and control rods. Extremely resistant to thermal shock, and with no danger of melt-down, graphite is the logical solution to the higher-temperature reactors of the future.

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Circle 1945 on Page 48-B

How Refractory Materials Withstand High Air Velocities and Temperatures

Three composites, silicon carbide plus silicon, chromium plus 28% alumina, and titanium boride plus 5% boron carbide, can resist high air velocities at 3800° F.

STRUCTURES AND SKINS of hypersonic craft, must be able to withstand such flight conditions as 2000° F. temperatures and high-Mach speeds without significant loss of physical and mechanical properties. In air at high temperatures, the deterioration of refractories is considerably influenced by their oxidation characteristics, particularly at high speeds. In still air, some refractories form protective oxides, but high-speed flight may continuously remove them by corrosion. Although most of the refractory materials resist this type of erosion, their oxides generally do not. Likewise, materials which oxidize rapidly are unsatisfactory. It follows that the most useful materials are those whose change in weight and surface condition is least.

With these variables in mind, 22 refractory materials were evaluated with a heated air jet (stagnation temperature, 3800° F.; pressure, 105 lb. per sq.in.; velocity, Mach 2). These materials had been screened from a large number on the basis of best thermal-shock resistance. Six had silicon carbide as the major constituent with carbon, silicon, or silicon nitride additions; five were titanium carbide cermets with nickel or molybdenum-nickel additions; four were alumina cermets with large proportions of chromium, partially replaced by molybdenum in one instance and tungsten in another; five were titanium boride with or without minor additions of boron carbide or nickel; and finally, one was chromium boride and one was silicon nitride.

For testing, hemispherical-nose cylinders (½ in. in diameter) representing each material were given four runs, lasting 30 sec. each, and allowed to cool to room temperature between runs. Specimens were weighed before and after each run, the effect on surface condition also being noted. Temperatures remained essentially constant during the last 25 sec. of each run, ranging from 2260° F. for the titanium borides to above 2550° F. for the titanium carbides.

There was no apparent interior changes in the specimens; all withstood four test cycles without apparent damage due to thermal shock.

The materials were judged principally on the basis of weight change in the specimens, although surface damage characteristics were noted and found to be consistent. No one class of materials was outstanding. Rather, of the three materials showing the best resistance to deterioration, one each represented three of the principal classes tested. These

(*Continued on p.* 192)

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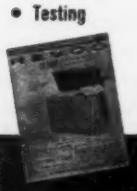

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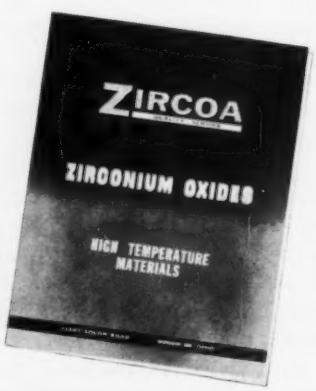

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Circle 1947 on Page 48-B

LINDE ELECTRIC WELDING

PLASMARC

New...very-thin, fused deposits with controlled dilution
New...high-speed, dross-free cuts in 5-in. thick metals

LINDE, inventor of plasma arc processes, announces *new* PLASMARC weld surfacing and *advanced* PLASMARC cutting. What is plasma arc? It is a flow of gas forced through an electric arc, constricted in a small-bore torch nozzle, and accelerated to form an intense jet. It combines electrical heat with the latent heat of highly-excited ionized gas atoms to reach one of the highest known metal-working temperatures (30,000° F.). It will melt any known metal.

A TRUE WELD

PLASMARC *weld surfacing* is true welding—not coating or plating—achieved by feeding powdered metal through the plasma arc into a weld puddle which freezes to form the deposit. Its precision eliminates excess buildup—ideal for such parts as valves, plowshares, seals . . .

PLASMARC weld surfacing gives precise control of penetration of overlay metal into base metal—as little as .005 in. or higher. Gives precise control of dilution with base metal—from 5% up to 50%. Provides one-pass deposits as thin as .010 in., as thick as 3/16 in., with a wide range of metals and alloys. Produces widths from ⅛ in. to 1 in. or more, speeds over 20 ipm at 95% deposition efficiency, flatter and smoother deposits than other fusion processes.

4000 FT./SEC. VELOCITY

PLASMARC *cutting* uses a near-sonic velocity plasma jet (4000 ft./sec.). It easily melts-and-forces a narrow kerf through both ferrous and non-ferrous metals with little or no change in metallurgical properties. After six years' success, it is replacing shearing, sawing and powder cutting—slower methods which often require machining of the cut edge.

PLASMARC cutting has been further developed—heavy-duty equipment, higher current capacity—to handle increased metal thicknesses. It cuts aluminum, magnesium and copper up to 5-in. thick and stainless steel up to 2 in. thick, dross-free. It clean-cuts 4-in. thick stainless, nickel, carbon steel (requires no iron powder), "Monel," "Inconel," cast iron, high-alloy and clad steels. It makes precise, high-speed cuts up to 300 ipm, holds tolerances to 1/16 in., leaves a heat band as thin as .006-in. wide.

Get full details . . . see a "live" PLASMARC demonstration. Contact your local LINDE office or write direct.

PLASMARC weld surfacing with "Haynes Stellite" 157-M alloy on periphery of ⅛-in. mild-steel disc.

PLASMARC cutting 3-in. aluminum, dross-free, at 20 ipm.

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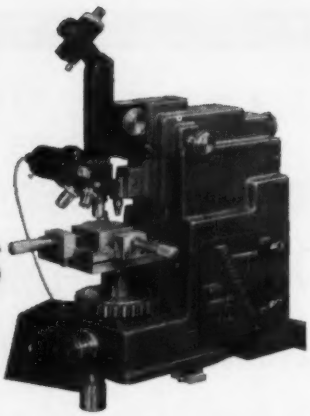

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Circle 1949 on Page 48-B

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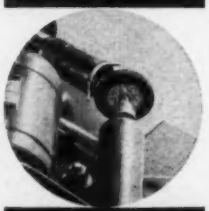

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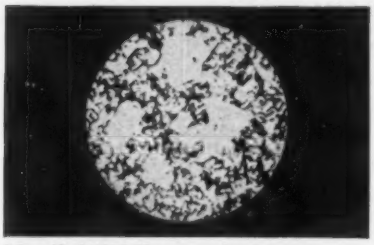
Circle 1950 on Page 48-B

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Abrasives, 99.98% pure alumina, simplify polishing of metals

Once it was a complex art to put precision finishes on metals. Polishing, sharpening, honing involved many abrasives and techniques. Now, with LINDE *alumina* abrasives, metallographic polishing is routine.

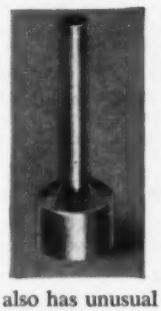


Magnified 1500 X—a sample of tungsten carbide with 6% cobalt binder polished by modified procedure for hard materials. (Murakami's etch).

In three grades LINDE 0.3 A (alpha alumina), LINDE 0.05 B (gamma alumina), and LINDE 1.0 C (alpha alumina)—these low-cost, fast-cutting white powders can be used with many materials. LINDE 1.0 C removes material rapidly; LINDE 0.3 A cuts quickly, yet leaves a clear, unsmeared finish; LINDE 0.05 B cuts slower but produces a finer finish. Uniformity of the particle size eliminates levigation in finishing.

Powders can be used dry, or mixed with water or other vehicles to make a thin slurry or heavy paste, or compounded with waxes in convenient stick form. Both are highly resistant to common acids. Check, send the coupon.

Now—high workability for tungsten in crystal form



Ingots of LINDE crystal tungsten can be worked into intricate shapes for electronic, other applications. It can be done at room temperature, using standard machine tools. Metal has no porosity, relatively low impurity, is less brittle than PM tungsten. Crystal tungsten also has unusual ductility, has been drawn into wire as fine as 1 mil for greater yield of finished product from starting ingot. Check, send the coupon for details.

High-grade wear from lower-grade metals —with tungsten carbide coatings

Bearings on the torque meter shaft of a turbo-prop aircraft engine gave only 50 hours operating life, even though the bearings were heat-treated. The short life was caused by severe fretting corrosion. Then the bearing surfaces were given a tungsten carbide coating with LINDE's Flame-Plating process. Service life is now greater than 1500 hours.

A critical tolerance had to be maintained between a ball piston and the piston wall in a hydraulic pump. Carbide inserts mating with steel balls proved unsatisfactory due to differential expansion at operating temperature. Carbide balls added considerable weight. The problem was solved with Flame-Plated steel bushings which had the correct expansion rate and a wear resistance equal to solid carbide—at considerably less weight.

Aluminum toughened

In another situation, aluminum rocker arms were being used in an aircraft heater mechanism to keep weight under overall requirements. But, because of severe sliding abrasion, the relatively soft metal lasted only about 100 hours. When the wearing surface was given a precision coating of tungsten carbide, service life jumped to more than 1000 hours. And the desirable light weight of aluminum was not lost.

These are typical examples of how LINDE's custom-coating service can be used to upgrade many ordinary metal parts by coating their wearing surfaces with tungsten carbide, aluminum oxide, tungsten, molybdenum, other oxides and materials. The thin coatings multiply wear performance many times over—but at the lower costs and with the retention of the other desirable properties associated with the base metals.

If you need technical information on particular problems with wear caused by abrasion, corrosion, erosion—even under conditions of severely high temperature, high load, or absence of lubricant or cooling—LINDE can help you. Check and send the coupon below.

PHYSICAL DATA—FLAME-PLATED COATINGS

COATING DESIGNATION	LW-1	LW-1N	LW-5	LC-1A	LA-2
Approx. Composition by weight	Tungsten Carbide + 6% to 8% Co	Tungsten Carbide +13% to 16% Co	25% WC +7% Ni + mixed W-Cr Carbides	85% Cr_3C_2 + 15% Ni-Cr	99% + Al_2O_3 (gamma)
Hardness Vicker's (VPN_{300})	1200 to 1450	1050 to 1150 VPN 70 to 71 R.	1000 to 1200 VPN	850 VPN	1000 to 1200 VPN
Maximum temp. in oxidizing atmosphere	1000°F.	1000°F.	1400°F.	1800°F.	1200°F. to 1800°F.
Coefficient of thermal expansion	4.0 x 10 ⁶/°F. Avg. 70 to 1000°F.	4.7 x 10 ⁶/°F. Avg. 70 to 1000°F.	4.6 x 10 ⁶/°F. Avg. 70 to 1400°F.	6.4 x 10 ⁶/°F. Avg. 70 to 1800°F.	3.9 x 10 ⁶/°F. Avg. 70 to 1832°F.
Modulus of Rupture	67,000 psi	80,000 to 106,000 psi	40,000 psi	75,000 psi	22,000 psi
Modulus of Elasticity	44 x 10⁶ psi	42 to 40 x 10⁶ psi	17 x 10⁶ psi	22 x 10⁶ psi	16 x 10⁶ psi
Porosity	0.5%	0.5 to 1.0%	0.5%	0.5%	1.0%
Specific Gravity	14.2	13.2	10.1	6.54	3.45
Specific Heat	0.048	0.056	0.070	0.127	0.196
Thermal Conductivity	5.3 at 500°F.	5.3 at 500°F.	3.8 at 500°F.	4.3 at 500°F.	0.86 at 500°F.
Main features	Extreme wear resistance	Excellent wear resistance + increased resist. to mechanical and thermal shock.	Excellent wear resist. to higher temps. Improved corrosion resist.	Good wear resist. at high temp. or in corrosive media. Resists flame impingement.	Excellent resist. to wear, chem. attack and high temperature deterioration.

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- ☐ LINDE Alumina Abrasives
- ☐ LINDE Arc Crystal Tungsten

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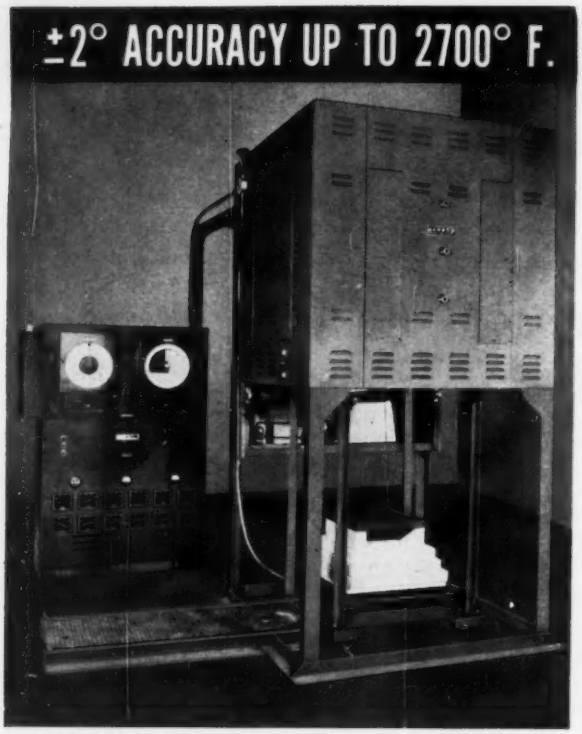

Model NMR-12E non-metallic resistor Harrop furnace. Mechanical or hydraulic elevator. Shuttle hearth also available.

Harrop electric atmosphere furnace is designed for precision testing and small parts production

Here is a furnace that is adaptable to many uses, such as crystal growing and firing of ferrites, titanates and similar electronic ceramic parts. Instrumentation can be supplied for any firing requirement, both in respect to control and to control forms affecting the time-temperature-atmosphere relations.

Harrop NMR Series elevator furnaces are available in two firing chamber sizes . . . 12″ x 16″ x 12″ and 20″ x 26″ x 20″. They fire rapidly to ± 2° F. accuracy within their range of 2000° to 2700° F. Cooling can be quickly accomplished by an external sealed heat exchanger to follow a program controller.

Within the area of Harrop's broad scope and varied abilities, you may well find the solution to your problem relating to

- the controlled application of heat
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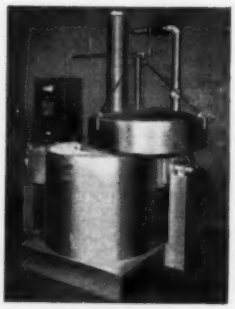
To secure a prompt, objective evaluation of Harrop's ability to help you . . . write Dr. Robert A. Schoenlaub, Director of Research, Harrop Precision Furnace Co., 3470 East Fifth Avenue, Columbus 19, Ohio.



Gas-fired Harrop furnace, GFHT Series, available in both floor and elevator types. Range of setting spaces from 8" dia. and 14" height to 36" dia. and 48" height. Standard temperature range to 3300° F., higher if desired.

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Circle 1952 on Page 48-B

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It concentrates in 340 pages the scientific and engineering information in the influence of alloying elements in steel, the actual function of various elements incorporated in alloy steels. It shows the extensive list of properties that may be altered by alloying elements, through their effects on microstructure.

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Authors: Dr. Edgar C. Bain
Dr. Harold W. Paxton

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Charles Saenger, Chief Metallurgist for the Illinois Tool Works in Chicago, Illinois.

CHARLES SAENGER tells how Lindberg equipment produced better cutters and hobs

QUOTE

"Unground form cutters and hobs require certain refinements above and beyond those needed for ground tools. Our Lindberg-Upton salt-bath units and daily chemical control of the salt-bath solutions help us maintain an excellent surface condition and hold to critical dimensional tolerances and close hardness range required by these tools. We are very well pleased with the consistent, trouble-free service our Lindberg-Upton furnaces have provided month in and month out."

The success of Illinois Tool Works in producing their top-quality unground form cutters and gear hobs is a well-established fact. The banks of Lindberg-Upton furnaces in their plant provide quality control in high speed steel hardening through the ability to hold rigidly the desired temperature and also assure proper salt conditions at all times.

The solution to any salt-bath furnace requirement is easy to find. Lindberg, through an exclusive agreement with Upton Electric Furnace Company, can offer high and low temperature furnaces for every production process where salt-bath equipment is needed. For complete information just call the nearest Lindberg representative (he's listed in your classified phone book) or, if you prefer, write us direct. Salt Bath Furnace Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, Spain, Switzerland and West Germany.

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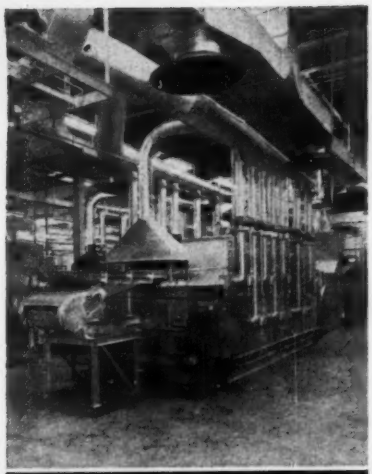
Circle 1959 on Page 48-B

One of the Lindberg-Upton Salt Bath Furnaces at Illinois Tool Works



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46 YEARS OF ENGINEERING LEADERSHIP

Circle 1954 on Page 48-B

Refractory Materials . . .

three that showed essentially no weight change were: silicon carbide with silicon, which showed very slight surface erosion; chromium with 28% alumina, which formed an adherent yellow-green coating; and titanium boride plus 5% boron carbide, on which little surface change was noted. As far as use in airborne units is concerned, the silicon carbide has an obvious advantage – the alumina cermet is nearly twice as dense and the titanium boride is even heavier. M. W. HAWKES

Digest of "Investigations of the Deterioration of 22 Refractory Materials in a Mach Number 2 Jet at a Stagnation Temperature of 3800° F.", by B. W. Lewis, NASA Technical Note D-906, June 1961, National Aeronautics and Space Administration, Washington, D.C.

How Alloys Affect Hot Cracking of Stainless Steels

According to tests, tungsten and manganese reduce hot cracking tendencies, while silicon and titanium increase them.

THIS IS A CLEAR and detailed discussion of the application of the cast pin tear test to determine the effects of the chemical analysis of the cracking of stainless steels as they cool after welding. The prime object of the test is to submit the as-cast test piece to a uniform tension as it cools; this tension can be highly concentrated at a given area across the section of the piece being tested. By careful control of temperature and the use of standard lengths of a copper cylinder (which is heated by the cooling test piece, and, in expanding, furnishes the necessary tension), we apparently can determine quite accurately the effect of a given variation in chemistry on the ability of the test piece to resist this tension without fracture.

Although the data obtained seems to be local in its application, it is still quite remarkable in its apparent scope and engineering value. It is information which should be welcomed by everyone who has to be in any way responsible for heat-resisting alloy steel applications, the rolling of stainless steel in ingots and stainless steel welding, and the like.

Apparently, the results of these tests indicate that the work done many years ago in developing high speed steel was on sound ground in indicating tungsten, chromium, manganese and vanadium as the best alloys.

I believe this is a commendable contribution to a better understanding of the effects of some alloying conditions on the hot as-cast strength of heat-resisting stainless steels. I am certain it is information which will be referred to many times; it should stimulate research work to find out what makes tungsten and manganese *reduce* hot cracking, and silicon and titanium *increase* hot cracking of the as-cast structure.

H. W. MCQUAID

Digest of "Effects of Alloying Additions on Hot Cracking of Austenitic Chromium - Nickel Stainless Steels", by Frederick C. Hull. Paper (Preprint 78) presented at the A.S.T.M. annual meeting, June 1960.

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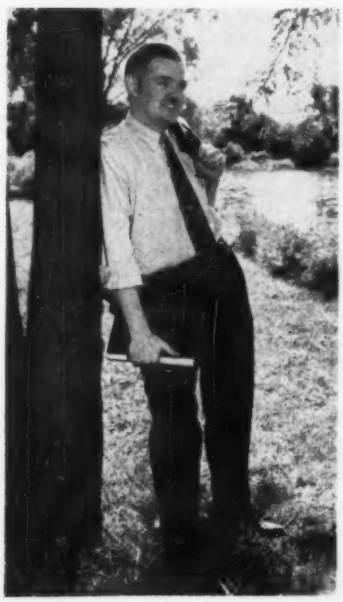
Materials and fabrication problems, stress-corrosion, fracture toughness, metallurgical tests – all these idea filled subjects and more are covered in this new, authoritative A.S.M. book. Authors from Aerojet-General, U. S. Steel, U. S. Naval Research Laboratory, General Motors, N.A.S.A., Mellon Institute for Industrial Research, United Aircraft and National Academy of Sciences make this an essential book for your use now – and for your reference library–*284 pages–8½ × 11–hard cover–ASM Members $9.60. Nonmembers $12.00.* Clip and send to ASM Technical and Engineering Book Information Service, Metals Park, Ohio.

BEHIND THE BYLINES

Three articles on Modern Heat Treatment lead off this month's magazine – and first of the three is Richard J. Gould's report on "A Superior Microstructure for Optimum Induction Hardening". The article is based on his work as a metallurgist in the actuator department of the Saginaw (Mich.) Steering Gear Div. of General Motors. His studies at the University of West Virginia were interrupted by military service but at the war's end he returned to school – transferring to Michigan College of Mining and Technology – and was graduated with a B.S. degree in metallurgical engineering. His background in industry – before coming to Saginaw in 1954 – includes work as a metallurgist in charge of heat treating at the Midwestern Machinery Co. in Joplin, Mo., as inspector-observer at Jones & Laughlin Steel Corp. in Pittsburgh, and as foreman at the Eaton Foundry in Vassar, Mich. After working hours, he concentrates on his family (he has two lovely daughters, 14 and 8, and a dachshund) and golf, skiing and photography.



A method for strengthening semiaustenitic stainless steels is discussed on p. 78 by David C. Ludwigson, a project leader in Battelle's ferrous and high-alloy metallurgy division in Columbus, Ohio. Dave joined Battelle Memorial Institute in 1956 after earning his B.E. degree in metallurgy from Yale University. He continued his studies part-time at Ohio State University and in 1959 received his M.S. degree. His principal efforts have been aimed at developing new stainless steels and improving existing grades. In addition he handles stainless steel technology for Battelle's Defense Metals Information Center.

He lists color photography as

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46 YEARS OF ENGINEERING LEADERSHIP

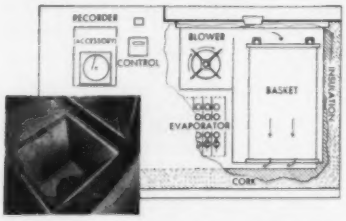
Circle 1955 on page 48-8

HARRIS BASKET CHILLING ATTAINS NEW STABILITY AND HARDNESS FOR NORMA-HOFFMANN BEARINGS

"Our Harris Production Chilling Cabinet attains dimensional stability in our bearings along with a hardness higher than normally obtained by heat stabilization methods," says Richard D. Robertson, Vice President of Manufacturing for Norma-Hoffmann Bearings Corp., Stamford, Conn.

His comment tallies with those of hundreds of other officials of America's foremost manufacturers who are achieving, at the sub-freezing range of the temperature scale, metal properties never possible with conventional heat treating. The reliability of Harris equipment in these applications is testifying to Harris' pioneering background since 1934 in servicing and engineering refrigeration equipment for the most exacting requirements.

Norma-Hoffmann's Harris Model 33L-A2-75 Heavy Duty Chilling Cabinet with solid wall basket refrigerates 500 lbs. of steel from room temperature to -120°F. in 1½ hours with ambient room temperature of 100°F. Total adjustable temperature range is 0°F. to -150°F. Indicating controlling thermostat sensitive to 1°F. One year warranty and 30-day service agreement.



Loose parts easily handled in solid wall basket with screen bottom for efficient air circulation and rapid heat transfer. Blower insures uniform temperature throughout chamber.

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Circle 1956 on Page 48-B

one of his hobbies – favorite subjects include his wife and daughter and vacation scenes. He also confesses to an addiction to contract bridge. In his own words, "I get withdrawal symptoms if I don't play at regular intervals".

In the second article in our two-part series on 2219 aluminum alloy three Alcoa engineers, F. R. Collins, F. G. Nelson and I. B. Robinson (shown right to left in the photo below), discuss welding characteristics and properties of weldments. Part I which appeared in September dealt with general characteristics, properties and corrosion resistance. Mr. Collins, head of the joining section at Alcoa's Research Laboratories in New Kensington, Pa., has been on Alcoa's staff since graduating from Brown University in 1947 (with a degree in electrical engineering). His work has included reduction, refining and plating processes for aluminum and since 1955 welding, brazing and soldering. He became head of the joining section in

the process metallurgy division in 1958. Spare-time activities include music and attempting to keep up with his two sons and three daughters.

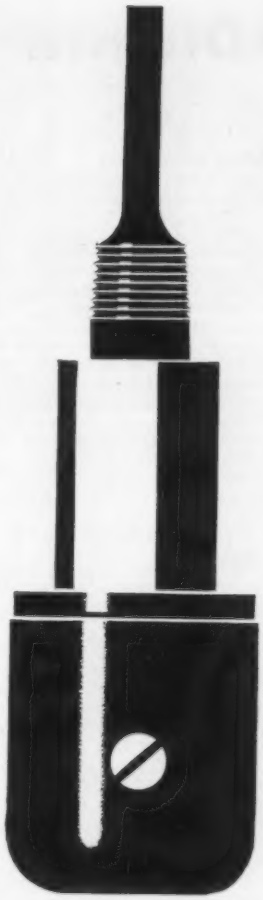
F. G. Nelson joined Alcoa in 1946 as a research engineer in the mechanical testing division. After graduating from Virginia Military Institute in 1941 with a B.S. degree civil engineering, he worked for the Martin Co., then entered military service. At Alcoa he has been responsible for analyzing information of the mechanical properties of all types of welded joints and the exploration of the extent of the heat-affected zone in weldments. His wife and three children share his interest in traveling, philately, photography and scuba diving.

Following his graduation from Colorado School of Mines in 1951 with a degree in metallurgical engineering, I. B. Robinson joined Alcoa's process metallurgy division where, as a research engineer in the joining section, he worked on various phases of aluminum joining. He spent two years in the Army, then returned to Alcoa and in 1960 was transferred to the newly formed Technical Information Department to work on information retrieval. He received his M.S. degree in 1958 from Carnegie Institute of Technology. An incurable do-it-yourselfer, he exposes his wife and daughter to a wide variety of projects ranging from woodworking to dramatics.

Yet another article on aluminum 2219 is by two engineers at Boeing, Stanley L. Sears and Richard S. Crial, who discuss the application of 2219 to the Bomarc fuel tanks. Stan Sears (shown, above, on the right, with his co-author) was studying at Oregon State College when World War II broke out. After more than four years in the Army, he resumed his college work at Oregon and graduated with a B.S. degree in 1950. Since 1951 he has worked at Boeing in the engineering aspects of welding and tank fabrication. Married, with four children (three sons and a daughter), he enjoys chess, local travel, camping, clamming and just plain touring.

Dick Crial served on destroyers in both the Atlantic and Pacific during World War II, and after his release attended New Mexico School of Mines. Graduating in 1951, he worked as a mining engineer in various mines until later that year when he was recalled into the Navy. He joined Howe Sound Mining Co. in 1954 as a mining engineer, then in 1957 came to Boeing to work on aluminum welding. Married, with an 18-year-old daughter (now attending Western Washington State College), his primary recreational activities are hunting and fishing in Washington's Cascade Mountains.

The third and last part of "How to Get the Most From Phosphating Systems", the eighth in our series on better finishing, appears on p. 108. George H. Pimbley, group leader of metal surface conversion coatings in the research and development department at Turco Products Inc., Wilmington, Calif., has 41 years industrial experience, including paint manufacturing and research and development on conversion coating materials. He's shown in the photo with Howard Fernbach (left), one of his assistants, evaluating phosphated specimens. A member of A.S.T.M., he is active on Committees B-8 and D-1.



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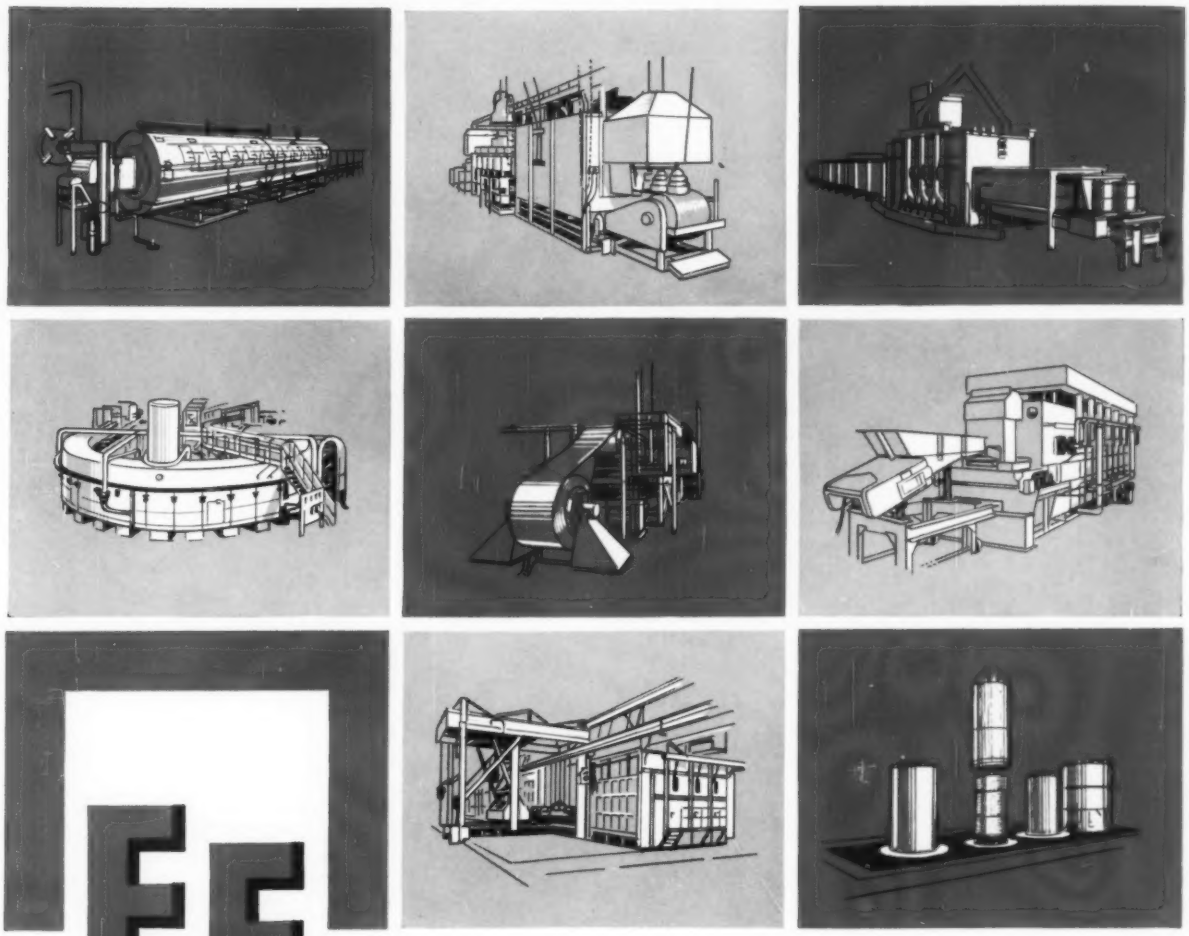

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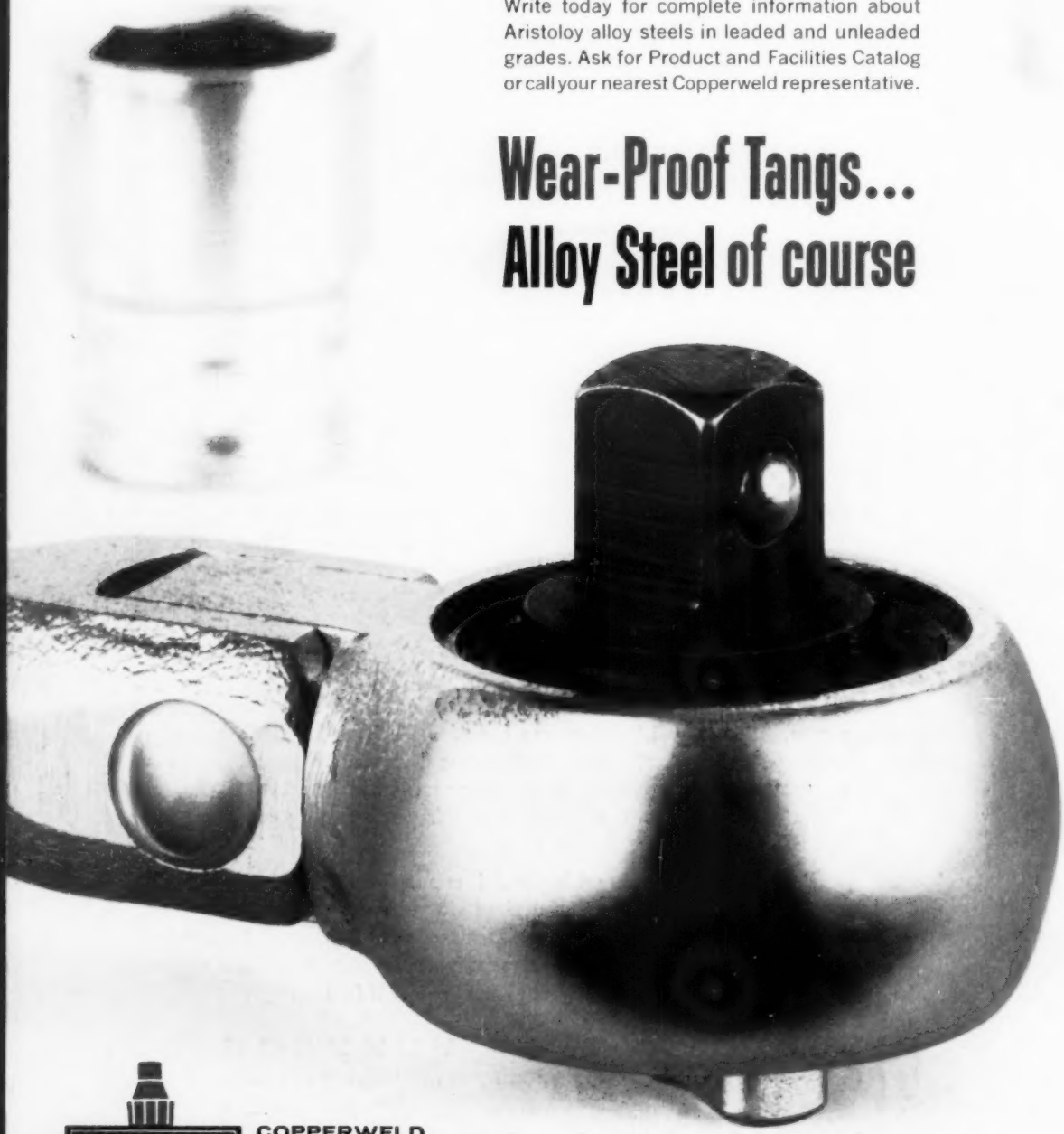

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